# THE INFLUENCE OF ATMOSPHERIC DUST UPON THE FLORENCE SOILS OF EASTERN KANSAS

By

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## INTRODUCTION

Dust, as it exists in the atmosphere has long been observed, and for many years, the presence of dust in the atmosphere has been mentioned in contemporary writings. E. E. Free (7) indicated that dust, falling from the atmosphere, was recorded as much as three hundred years before Christ, and that, during the Middle Ages, heavy influxes of atmospheric dust were believed to be of extra-terrestrial origin when it was observed to fall along the western coast of Africa and northward to Italy. This illustrates that even that far back in history, people were cognizant of dust in the atmosphere.

## REVIEW OF LITERATURE

### Promoting Influences

Because dust has long been recognized as a constituent of the atmosphere, and because it is genetically foreign to this environment, there must be outside forces which promote this phenomenon. Choun (6) indicated that the main factors which promoted the dust storms of 1932-1937 in the midwestern section of the United States included: 1) marked deficiency of soil moisture, 2) elevated summer temperatures, 3) careless and irresponsible cultivation practices, 4) abnormally high wind velocities and 5) over-grazing. Several sub-factors could have been included also. However, he stated that the main source of dust appeared to be influenced more by the lack of effective precipitation than by the other factors. Free (7) recognized that the two chief protectors against wind erosion were vegetative cover and soil surface moisture. Woodruff and Siddoway (20) stated that the rate of soil movement varied directly as the cube of the wind velocity and approximately inversely as the square of the effective soil moisture. Choun (6) stated, "Generally speaking, wind erosion takes place

under extremely dry conditions with a wind velocity of 20 mph on all land which has been in cultivation three or more years". He further found that northerly winds seem to be the most potent in respect to erosion of the soil surface as they are of slightly greater velocity, colder, heavier, and have a greater carrying power near the ground. Chepil and Woodruff (5), in their search for a usable wind erosion equation, determined that a wind threshold drag velocity of 15 cm. per second (about 10 miles-per-hour) at a height of one foot above a smoothed soil surface was sufficient to initiate movement of the most erodable soil particles. They further found that the most important basic cause of wind erosion was depletion of vegetation or vegetative residue on the land.

Because wind is one of the necessary elements connected with the uplift of dust into the atmosphere, it would be well to examine it more closely. Free (7) wrote,

> "The wind is made up of many momentary currents blowing upward and downward as well as horizontally and what we call the wind direction is the resultant of these momentarily variable directions.
>
> The atmosphere is in such general and constant circulation, vertical as well as horizontal, that material fine enough to remain in suspension for any appreciable time can be carried far above the surface simply by the normal movements of the air currents."

Chepil and Woodruff (5) indicated that dust particles, which had been kicked up into the moving wind stream by other saltating dust grains, could be lifted to an indefinite height by upward velocities of wind eddies. The velocity of these upward eddies were at least two to three miles-per-hour. This, in conjunction with the aforementioned reasons for the availability of dust, explains the natural occurrence of dust in the air.

## Dust Transportability

Because wind is necessary for the elevation of dust from the soil surface into the air, so also is it responsible for the transport of this dust to different locales, depending upon the wind direction, velocity and duration. Free (7) indicated that visible dust has been observed to travel distances of up to 2,500 miles from its place of origin. More commonly however, its greatest range of transport is less than 1,000 miles. Martin (11) stated that the dust in the duststorms in the spring of 1936, which originated in northwestern Texas, western Oklahoma and Kansas, and eastern New Mexico and Colorado, was transported as far east as Maine. Commonly however, it was deposited closer to the source area with some deposition in Kansas, Nebraska, Missouri and Iowa. Robinson (14) upon examining the "brown snow" which fell in New Hampshire and Vermont February 24, 1936, stated that because of a high ratio of $Si0_2$ to $Al_2O_3$ and $Fe_2O_3$ (which is characteristic of western pedocals), a high lime content, and some $CaCO_3$ present in the dust, that it must have originated west of the Mississippi River at least. This is a minimum of 1,100 miles. Byers (3), also studying the brown snowfall in New Hampshire and Vermont wrote that the origin of this dust was easily traced to the five-state area of Texas, New Mexico, Oklahoma, Colorado, and Kansas which, on February 23, was engulfed in severe dust storms. The path followed by this dust was from around Amarillo, Texas, northward through eastern Colorado and New Mexico, western Oklahoma and Kansas, swinging eastward over central Iowa, the lower Great Lakes, Buffalo, N.Y. and finally New Hampshire. The dust at Omaha was at an elevation of from 2,200 to 3,400 meters and at Buffalo it was at an altitude of 1,800 to 3,000 meters.

Miller (12), in studying the dust cloud of February 13, 1933, found that winds with a velocity of 45 to 63 miles-per-hour over an area between Bismarck, North Dakota and Kansas City, Missouri on February 12, picked up great clouds of

dust and carried them at elevations up to 9,000 feet northeasterly to Buffalo, New York, south through Pennsylvania, Tennessee, and finally terminating in Mississippi, Alabama, and Georgia.

Fifteen years prior to Miller's study of the 1933 dust cloud, Winchell and Miller (19) stated, after studying the dust falls of March 1918, that the dust in the atmosphere of the central and eastern states was not of local origin because of the snow cover, vegative cover, and soil moisture of these states as well as the incompatibility of the transported dust mineralogy. Free (7), not only illustrated the great distances of dust transport but also supported the concept that the mineralogy of the dust itself could not pinpoint any exact place of origin. Because of this, he asserted that one must rely on indirect evidence such as the existence of a probable source area in the direction from which the wind is blowing, meteorological data by which the path of the storm can be traced, etc., to more closely fix the area of dust origin.

All the foregoing data point up the necessary requirements of aridity, scanty vegetation, high wind velocities, etc., for the presence of the dust in the air as it is commonly visualized. Sears (15), added another element of source when he considered the transported dust after it had settled out of the atmosphere. He explained as is commonly believed, that the vast blankets of loess which envelop parts of the earth, consist of material deposited by melting glaciers, picked up by the winds, and carried oftentimes hundreds of miles to its final point of deposition by these winds. He further stated the necessity of aridity for this occurrence.

## Size Selectivity

Apparently there is an ideal size for maximum pickup and transport of

atmospheric dust. Woodruff and Siddoway (20) stated that the soil erodability factor of the wind erosion equation is related to the soil cloddiness and increases as the percentage of soil fractions greater than 0.84 mm in diameter decreases. Winchell and Miller (19), in their study of the dustfalls of 1918, found that the size of the dust particles ranged from 3 to 100 microns but over half of the dust fell in the size range of from 10 to 25 microns. Alexander (1), upon examination of some 1933 dust, stated that the dust particles which fell on Buffalo had a diameter or length which ranged from 5 to 500 microns but that the larger percentage of material was about 20 microns in size. Robinson (14), analyzed a dust aliquot of the brown snow of New Hampshire and Vermont in 1936 and found the following size range and percentages:

| | |
|---|---|
| Greater than 50 microns | 2.2% |
| 20.0 to 50.0 microns | 0.7% |
| 10.7 to 20.0 microns | 28.4% |
| 6.6 to 10.7 microns | 27.6% |
| 5.0 to 6.6 microns | 7.7% |
| 3.1 to 5.0 microns | 18.8% |
| 2.0 to 3.1 microns | 9.2% |
| less than 2.0 microns | 5.4% |

Udden (18), appeared to be among the first to study dust quite extensively and in his study in which he collected and analyzed dust which settled on the sills and arms of chairs of moving trains he found the following results. Fine sand was too heavy to remain in air suspension during periods of the highest normal wind currents next to the ground. Very fine sand and coarse silt are just on the limits of size which is subject to effective suspension, and particles which have a diameter less than 1/32 mm. (31 microns) will not readily settle from the atmosphere during periods of strong wind velocities. There were only small quantities of particles less than 1/64 mm. in diameter "presumably because such particles tardily settle even in ordinary low winds". He found that dust particles which are capable of suspension in strong winds must have a diameter less than 1/16 mm. and that particles less than 1/4 this size are hindered from

settling out of winds of this velocity. He qualified this statement when he added that when the dust load exceeded a certain limit, then even the finer dust particles would flocculate and readily settle out of suspension.

In an experiment of a different nature Udden (18) smeared broomcorn whisks with glycerine and elevated them to a height of 90 feet on poles. The heads were collected every day and the dust analyzed. The size of the dust fraction adhering to these heads ranged from 1/32 to 1/64 mm. Substituting muslin for the broomcorn whisks did not alter the results of the experiment.

## Mineral Composition

Although the size of dust particles is of importance in the transportability and soil modifying influence of dust, it is probably not of any more importance that the kind of minerals present. Winchell and Miller (19), found the predominant minerals in the March 1918 snowfall to be quartz and feldspars. They further stated their theory that physical weathering held precedence over chemical weathering because the dust was well sorted and very fine, contained abundant limonite and hematite, unaltered feldspars, and some kaolin. The place of origin was fixed as the relatively baren southwest because of only 5% organic matter content. Alexander (1), in 1933 found the dust over Buffalo, New York to contain volcanic glass, quartz, feldspar, mica, tourmaline, zircon, hornblende, diatom tests, spores, pollen and vegetable fibres. The volcanic glass consisted of two separate types, one colorless and containing inclusions believed to be either gaseous or liquid, and the other exhibiting black coloration, suggesting basaltic glass. The quartz was clear and unstained. The sample contained about 10% organic matter which consisted of encrusted protozoans and spores of microfungi, ferns, and mosses.

Smith and Twiss (16) found similar minerals in their study of dust in 1963 and 1964. The predominant minerals were quartz, aggregates--both unstained and stained with iron oxides-and amorphous silica believed to be of plant origin. Traces of feldspars, micas, lamprobolite, zircon, hornblende, tourmaline, epidote, magnetite and ash shards were all identified occasionally in the sand and silt fraction while the clay sized fraction commonly included kaolinite, illite, montmorillonite, feldspars and quartz. Oxidizable material, considered primarily organic matter, made up from 10 to 20% of the material. Sears (15) stated: "Over half of the dust in the lower atmosphere is composed of local earth particles, about 1/4 contains carbon, evidently of industrial origin, while the remaining quarter is of miscellaneous makeup, including tiny salt crystals...". Peck (13), found that rain water and snow melt in 1916-1917 contained up to 37 ppm. sulfates, 0.35 ppm. nitrates, and 18.62 ppm. chlorine. Ehrneberg (7), in the middle 1800's believed that he had identified particles, especially diatoms, from every part of the world in atmospheric dust. However, this dust is now believed to have originated in the Sahara.

## Total Amount

Perhaps overshadowing the importance of the size of the dust particles and the kind of dust particles is the total amount of dust that settles from the atmosphere. Robinson (14), estimated that the amount of dust in the brown snowfall of New Hampshire amounted to about 10 tons per square mile. Winchell and Miller (19) found that during the dustfalls of 1918, deposition occurred in a region extending from Wisconsin and Ohio through New Hampshire, and that the amount collected at Madison, Wisconsin amounted to four grams per square yard, 13.5 tons per square mile, or 420 pounds per acre. In this study, most of the dust came down with rain or snow. Udden (18), found a correlation

between the wind velocities and the quantities of dust caught while Free (7), stated that: "showers of fine dust sometimes occur unaccompanied by any strong wind". Udden estimated that on the average, and figuring conservatively, in the western states where dust storms are possible, about 850 million tons of dust is carried 1,440 miles per year. Free estimated, again conservatively, that an average of 0.01 inch of dust accumulates per year on the surface of the soil in the United States west of the Mississippi River. This amounts to 1 inch per century assuming no erosion loss. He also asserted that dust storms may carry from only a few tons up to 126,000 tons of dust per cubic mile or up to 50 tons per square mile. Free found data collected by Hellmann and Meinardies on a dust storm in March 1901, indicating that that single storm deposited an average layer of 0.239 mm. thickness of dust upon the soil surface. One storm such as this every five years would build up 4.78 mm. of soil per century and over the past 30 centuries would produce 143.4 mm. (five and one-half inches) of soil. This was immediately qualified by stating that it is illogical to assume these figures as this dust is not permanent, but rather, it also is acted upon by weathering, leaching, and erosion. Smith and Twiss (16), found in 1963-64, that the average monthly fall of dust from the atmosphere at Manhattan, Kansas amounted to 52 pounds per acre and at Hays, Kansas to be 54 pounds per acre. These years, it must be pointed out, can not be considered abnormally dry and dusty years, but rather just average years.

## Resulting Influences of Dust

It was partly because of the availability and transportability of dust that this project was undertaken. Winchell and Miller (19), indicated that they thought there should be more emphasis placed on studying atmospheric dust

because of its ability to be transported great distances, because it includes both beneficial and detrimental spores, and because of its soil building characteristics. Sears (15) working more on the historical aspect of soil modifying characteristics of transported dust than the present soil building characteristics, used plant pollen from past sediments of dust to describe various climatic changes which occurred in a region of Mexico. This was accomplished because different climatic conditions promote and support different species of vegetation. Free (7), indicated that windborne dust being transported into an area quite remote from the place of origin, may very well carry into the area soil minerals abundant in the area of origin of the dust but deficient in the area of deposition. Thus, soils inheritantly deficient in certain minerals may receive, through dust transport and sedimentation, enough of the deficient mineral to meet its needs, even though they may be in very small total quantities. Robinson (14), added support to this theory by assuming a dust cloud with a concentration of 10 tons per square mile, 5.3% of which was $CaCO_3$. He calculated that this cloud would deposit 1,060 pounds of lime per square mile, or 1.7 pounds per acre, which for lime would not be significant. However, if the mineral were zinc, magnesium or some other micronutrient, it would be significant.

Miller (12), recognized the geologist's interest in dust because of the light it throws on the deposition of loess and the character of the minerals supposedly of aeolian origin. The quantity of dust falling from the atmosphere per unit area, especially that brought down by rain or snow, and the relative quantity of the different sizes, were two factors which would need to be incorporated in the geologists study of loess. He further recognized the value of wind transported dust in supplying potassium from the more arid western regions to eastern soils where the potassium was being more rapidly

utilized. Free (7) stated that the fertility level of a soil depended in large part upon the heterogeniety of the soil minerals which make up the soil and that rock disintegration alone could not supply this heterogeniety, but rather, various transporting agencies had to be relied upon to supply this phenomenon. Wind was one of the most important of these various transporting agencies because of the constant interchange between the atmospheric load and the soil particles from the soil surface. The impact of this interchange cannot be more aptly stated than when he said: "...large quantities of soil material are everywhere being moved about by the winds, and this transfer, by assisting the mixing of the soils, has been, and is, of the utmost importance to agriculture." Only by combining the impact of this statement with an equally appropriate one by Sears (15), can one begin to comprehend the need for a study such as this whereby vastly growing needs of more efficient food production need to be promoted to offset the demands of a world of exploding populations. This statement by Sears points up the availability of this nutrient rich dust when he said, "Dust itself is nothing new. Like the circle, it is the symbol of eternal time .... Dust is everywhere in the air we breathe, an invisible world of tiny bouyant particles, infinitely rich in its variety and with laws of its own."

## Reasons for Study

The purpose of this study was 1) to determine the possibility of a great enough influx of atmospheric dust to effectively modify the physical characteristics of the surface horizon of the Florence soil from its underlying parent material, 2) to determine the possibility of soil nutrients, or minerals containing available soil nutrients, being transported into the study area in

great enough quantity to affectively influence the fertility level of the surface horizon of the Florence soil, 3) to determine if the quantity of dust transported to this area is of great enough magnitude to affectively modify the texture of the surface of the Florence soil, 4) to study the possibility of determining the source or origin of the dust, 5) to determine if dust influx is significantly different for sites one-hundred miles apart, even though these sites are situated on Florence soils, 6) to measure the precision of sampling and repeatability of data collection at one site, and 7) to measure the influence of height of sampling upon the quantity and quality of the dust collected. The Florence soil was chosen for this study primarily because of its extensive north-south expanses of wind erosion resistant grasslands, an excellent "outdoor laboratory" for a study such as this. A description of the Florence cherty silty clay loam series can be obtained from the Soil Survey of Geary County, Kansas (17). A typical profile description includes horizons as follows:

| Horizon | Approximate Depth |
|---|---|
| $A_{11}$ | 0 to 8 inches |
| $A_{12}$ | 8 to 14 inches |
| $B_2$ | 14 to 24 inches |

Below 24 inches, the profile commonly grades rapidly to the parent limestone.

The distribution of the Florence soils extends in a north-south band through the Flint Hills and Osage Hills region of Kansas and Oklahoma respectively where it overlies the Florence, Schroyer, and Threemile limestones. These limestones are of the early Permian system of the Paleozoic era. This band is generally encompassed between the 96th and the 97th meridians and extends from southern Nebraska through Kansas and into northern Oklahoma. In addition to the limestone over which this soil occurs, Florence soil may be influenced by interbedded shale strata.

## MATERIALS AND METHODS

Basically, laboratory methods used in this study follow Jackson (9) or Kunze and Rich (10). However, because of the manner of dust trapping, character of material, and size of samples, certain details are different from these published recommendations. Therefore, it is necessary to describe laboratory as well as field procedures.

This study was carried on at three separate sites, one site located about 15 miles north of Manhattan, one site 15 miles south of Council Grove, and one site approximately 20 miles northeast of El Dorado, all in Kansas. The Manhattan site consisted of four containers resting on the surface of the ground, and one container elevated to 16 feet above the ground surface. The other two sites contained only one container at each site (see Plate I). The containers used were all standard 8 x 24 inch rain gage containers. All sites were fenced to restrict livestock activity and each container was topped with two standard soil sieves, the bottom sieve with 1.0 mm. openings and the top with 6.35 mm. openings. The elevated container used only one sieve, the large one, because plant seeds, leaves, etc. were not considered to be a problem. A liquid, either distilled water or distilled water plus ethylene glycol, was maintained in all the containers to entrap any dust which entered. Each site was personally selected or verified by qualified soil scientists, courtesy of the Soil Conservation Service, as being Florence cherty silty clay loam soil. Also, seven soil samples were taken at each site. These samples were taken at 1/2 inch intervals for the first 2 inches and at 1 inch intervals for the next 3 inches, giving a total of 7 samples to a depth of 5 inches.

EXPLANATION OF PLATE I

Fig. 1. The four surface and one elevated dust-catching containers located at the Manhattan site 15 miles north of Manhattan, Kansas

Fig. 2. The dust-catching container as it existed approximately 15 miles south of Council Grove, Kansas.

Fig. 3. The dust-catching container which was located northeast of El Dorado, Kansas.

## PLATE I

The sites were all selected on east by southeast facing slopes and surrounded by native grassland vegetation for a distance of at least 1,000 meters. The Manhattan site was the best range site according to rangeland classification guides. The Council Grove and El Dorado sites were slightly poorer sites and were more nearly equal in their rangeland qualities.

The dust samples at all three sites were collected as nearly as possible on the first of each month and usually all on the same day. They were collected by washing down the sieves and sides of the container with distilled water and rinsing the contents into a glass gallon jar. Following this, a measured amount of liquid (previously described) was then poured into the container, the sieves were replaced, and the unit placed back in its stand. This process was repeated with each container at each site. During the winter months, the sieves were removed so as not to impede the entry of snowfall. The jars were all capped immediately, and returned to the laboratory.

In the laboratory, each sample was allowed to sit for a few days until the dust particles in suspension had all settled. The supernatant liquid was then drawn off by gentle vacuum and either discarded or saved for solution elemental analysis. When ethylene glycol was present, the dust material was transferred to centrifuge tubes and washed from 4 to 6 times with distilled water. The dust material then was transferred to a weighed, numbered beaker and dried in the oven at 65 degrees C. Next it was cooled in the desiccator, weighed, and the weight recorded. The organic matter[1], or oxidizable portion of the dust, was removed by repeated (from 4 to 6) overnight treatments with

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[1]The terms "organic matter", "oxidizable material", or "organic material", as used in this manuscript refer to that portion of the sample which was of organic origin, either plant or animal, regardless of stage of decay, and which was destroyed by repeated treatments with 30% $H_2O_2$ as evidenced by a weight loss. This was necessary in that many samples contained numerous plant (and insect) fragments in various stages of decay that were so intimately intermixed with the mineral sample that separation was not feasible.

30% hydrogen peroxide, after which it was again dried, weighed, and the weight recorded. The difference between these two weights was considered the oxidizable organic matter portion of the dust.

At this point, if the sample weighed less than 0.05 grams, no further analysis was performed because it was felt that the desired accuracy in the interpretations of the results would be too subject to error due to the small size of the sample. In this case, the material was transferred to a capped-glass vial and kept for possible future study.

When the sample was large enough to fractionate, the following procedure was followed. After the oxidized weight was recorded, the sample was saturated with 5 to 10 ml of distilled water and allowed to soak overnight. Then approximately one ml. of 0.4N Calgon (sodium metaphosphate) solution was added to the sample, allowed to soak several minutes, and transferred, using a rubber policeman and wash bottle, to the mixing cup of a high speed mixer. Enough additional distilled water was added to the cup to insure complete immersion of the mixer paddles, and the solution was then mixed for a period of 15 minutes. The dust-water-Calgon suspension then was transferred to 100 ml. centrifuge tubes filled to the 9 cm. depth (net depth of fall), and centrifuged to separate the dust fraction at the two micron equivalent diameter size according to Stokes law. The clay suspension then was decanted into a clean beaker, leaving the sand and silt fraction in the tubes. One ml. of the Calgon solution and 70 ml. distilled water were again added to the sand and silt fraction of the dust in the centrifuge tubes (to give a Calgon concentration of 0.0005 gm./ ml.), thoroughly mixed, and centrifuged again. Decantation of the clays again followed. This step was repeated three more times until the clay suspension appeared clear or until all of the clay had been decanted. Three more identical steps followed, except no Calgon solution was added, to remove all Calgon from the sand and silt

fraction. The sand and silt fraction then was transferred back to the beaker where it was dried, weighed, and subsequently transferred to a capped vial for permanent storage. The clay suspension was further treated with saturated NaCl solution to flocculate the clays, and the supernatant liquid was drawn off and discarded. The flocculated clays then were transferred to test tubes where they were treated three times with 1.0N magnesium chloride solution to saturate the clays with the Mg ion. They then were washed repeatedly with distilled water (to remove the excess magnesium chloride) until they either refused to flocculate and settle, or until the decanted liquid gave a negative test for the chloride ion when treated with silver nitrate solution.

The separation of the clays into the coarse, medium, and fine size fractions was similar to the above in that the clays were dispersed with Calgon solution, mixed for 15 minutes, centrifuged again at the correct speed according to Stokes law, and the medium and fine clays (less than 0.2 microns) were poured off. Again, 3 to 4 more centrifugations were performed with Calgon, and at least three without Calgon. This resulted in two fractions, one a clean fraction of coarse clay and the other a Calgon-dispersed fraction of medium and fine clays. The coarse clays were stored in a clean test tube until they were ready to be oriented prior to X-ray diffraction. The medium and fine clays were flocculated again with NaCl and washed several times to remove the Calgon and NaCl. They then were dispersed again with 1% sodium carbonate, mixed in the mixing cup of the high speed mixer 15 minutes, and passed through the super centrifuge at the proper speed and at the correct flow to separate the fraction at the 0.08 micron size. The super-centrifuge separation is as outlined by Jackson (9). This process was repeated four times, resulting again in two fractions--the medium fraction (0.2 to 0.08 microns) and the fine fraction (less than 0.08 microns). These fractions were flocculated, the supernatant

liquid was drawn off and discarded, and both separates were transferred to stoppered flasks where they were treated three times with 1.0 magnesium chloride solution (to saturate the clays with the magnesium ion) and washed repeatedly with distilled water until free of the chloride ion. These samples were now also ready for orientation and X-ray diffraction.

A Norelco X-ray generator complete with instrument panel and recorder was used to irradiate the clay samples during the X-ray diffraction process. Prior to diffraction, the clays had to be properly oriented and prepared which consisted of concentrating the clays to a 1% suspension and evaporating two ml. of this suspension on a clean glass slide 27 by 46 mm. in size. This clay coated slide was irradiated using nickel-filtered, copper radiation with a diffractometer setting of either 38 or 40 kilovolts, 18 milliamperes, and a 1-degree slit system. Instrument panel settings included rate scale factors of 200, 500, or occasionally 1,000, a time constant of 2 seconds and various window settings of 16 and 11, 9 and 9, and 6 and 7 volts for level and width respectively. The different settings were the result of replacing the generator in 1965 and twice having the goniometer realigned. A scanning speed of 1 degree per minute was used with each clay sample monitored from 62 degrees to 1½ degrees two-theta. Remonitoring from 15 degrees to 1½ degrees two-theta was necessary when the clays were subjected to treatment with ethylene glycol when testing for expanding clays. When necessary, a separate slide prepared with the same sample was heated to 450 degrees C. or 600 degrees C. to assist in identifying certain clays. The results were recorded on diffractograms for permanent records.

Exchangeable cation studies were performed on a Perkin-Elmer Atomic Absorption Spectrophotometer, Model 303, and a Perkin-Elmer Flame Photometer, Model 146.

The method for determining the percentage of the minerals present in the sand and silt fraction was as follows. A scale was set up using the grain-size definitions of the National Research Countil (4), with seven different size categories ranging from 2 phi (ϕ) down to 9 phi (ϕ) (0.250 to 0.002 mm.). The median of each of the seven categories was then determined and recorded in microns. This figure was considered to be the average diameter of any mineral particle which, when viewed under the microscope, fell into one of these particular size categories assuming that the mineral grains of the dust were more spheroidal or cubic than plate-like. Dividing this value by two gives the radius of the grain and by inserting this value into the formula for determining the volume of a sphere ($4/3\pi r^3$), the equivalent volume of the sphere--in this case the dust-mineral grain, was derived. However, because absolute values were not needed, the constant $4/3\pi$ was dropped and only $r^3$ was used as an index of relative volume. Finally, to avoid exceedingly large figures, especially in the larger size fraction, the $r^3$ figure above was multiplied by 0.001. This gave a multiplying constant for the total number of mineral grains falling into any particular size category. For example, in the size category 6 to 5 phi (.0156 to .0312 mm.) converting to microns equals 15.6 to 31.2 microns. The median value of this size would be 15.6 + 7.8 or 23.4 which when cubed equals 12812.9 cubic microns. Multiplying by 0.001 then yields a multiplying constant of 12.8. This result is multiplied by the number of particles of each mineral falling into that particular category to produce an index more representative of relative volume in that size fraction than just particle numbers alone. The larger the size fraction the larger the multiplying factor, and hence the larger the volume percentage of that mineral present. Approximately 200 mineral particles were counted, identified, and placed into the proper size category, as they crossed one of the cross-hairs

of the microscope when the slide being viewed was advanced normal to that cross-hair.

The cation-exchange study of the dust was measured by transferring the dust suspension to a weighed beaker, drying at 65 degrees C. and weighing, resuspending in 50 ml. of 1.0N ammonium acetate and centrifuging until the supernatant liquid was clear. This liquid was decanted through filter paper into a flask and saved, and the process was repeated four more times. Next, it was evaporated to the recommended concentration for instrument determinations. A one ml. aliquot was diluted to ten ml. for the determinations of the exchangeable cations, Ca and Mg using the atomic absorption meter, while the undiluted sample was used with the flame photometer in the potassium determination. From these values, cation quantities were determined. The only differences between the two samples were the time factor (September vs. January) and the presence of ethylene glycol in the suspending medium of the January sample, which of course was washed out before the above described procedure was started.

## EXPERIMENTAL RESULTS

### Rate of Deposition

The rate of dust deposition from the atmosphere during the term of this study exhibited a distinctive seasonal variation. As is evident from Fig. 4, this study was set in operation at that time of year when the amount of dust settling to the earth's surface was declining, reaching a low in February. March yielded a sharp increase in rate of deposition followed by months in which the results at the sites were quite variable. For example, in April the amount of dust collected at Manhattan and Council Grove decreased while that at El Dorado increased. During May the amount of dust collected at Council Grove

and El Dorado decreased while at Manhattan the amount increased slightly. In June the results were similar to those of May, but in July the quantity of dust collected at Manhattan and Council Grove decreased while at El Dorado it increased somewhat. Finally in August, the quantity of dust collected decreased markedly at El Dorado, decreased slightly at Manhattan, and increased slightly at Council Grove. Nevertheless, over the period of study, the data indicated a general decrease in rate of atmospheric dust deposition in late summer and fall with a minimum at mid-winter. A substantial increase in dust deposition occurred in late winter and early spring and was followed by a general upward trend toward a uniform maximum in late spring and early summer. It should be noted that late summer and early fall of 1966 at the Manhattan site (see Table 1) did not duplicate the declining rate of dust deposition exhibited by the late summer and early fall of 1965, but rather, maintained the summer maximum through October. November and December of 1966 did, however, show a decrease in the rate of dust deposition similar to that of the same period in 1965. Data for months later than September, 1966 are available only for the Manhattan site because the Council Grove and El Dorado sites were phased out on September 1, 1966.

The monthly variation in the amount of dust was uniformly small with the exception of March, 1966 which exhibited an approximate eight-fold increase over February, 1966. Much of this increase can be attributed to a dust cloud which originated in New Mexico the first week of March and passed over the study area the next day.[2] This was determined by collecting one of the Manhattan replicates March 8, a few days after the dust cloud had passed over, and analyzing it

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[2]Personal communication from Mr. Merle Brown, State Climatologist, Manhattan, Kansas.

separately to determine if it was chemically or mineralogically different from that of the rest of the month. It was found that the first eight days of March yielded 25 pounds-per-acre of dust, about five times the total for February and about 1/2 the total for March.

The variation in amount among sites was quite small and quite uniform for the first seven months, August 1965 through February 1966 (See Fig. 4). During March 1966 however, the container at the Council Grove site collected a much greater amount of dust than the containers at the other two sites.[3] The April results indicated a fairly wide range among all three sites. During May, the differences began to narrow somewhat but the results for June indicated another wide difference--that of the elevated container[4] (See Fig. 5). Finally, the El Dorado results exhibited a wide difference in both July and August while the results at the other two sites approached uniformity.

All data are shown in graphical and tabular representation, however the March and June data were not used in statistical computations of analysis of variance.

During the term of study, the deviation in the total amount of dust collected among the five replicates at the Manhattan site was relatively small, with the elevated container most often exhibiting the greatest deviation from the mean (see Table 1). Of the surface containers, number 4 yielded the greatest deviation in August 1965 and again in March 1966. These two instances

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[3] Caused by a local influence--that of adjacent cattle feeding operations which occurred nearby.

[4] Caused by a local influence--being used as a perch by a hawk which nested nearby.

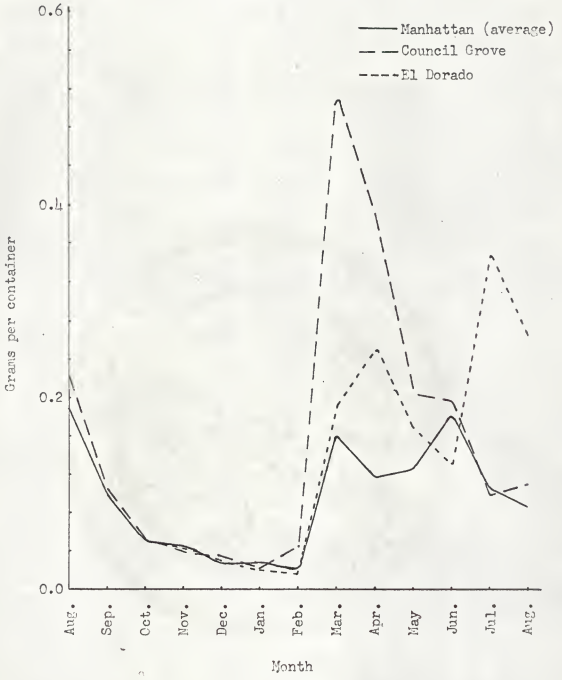


Fig. 4. The rate of dust deposition in grams per container at each of the three sites for the period August 1965 to August 1966. The Manhattan curve consists of the average of the four replicates.

were the only noticeably wide variations among the surface containers for the period of study. The elevated container was noticeably different from the mean of the surface containers for the following months--September and December of 1965, and February, March, April, May, June, July and August of 1966 (see Fig. 5).

A statistical analysis of variance was performed using the above data, testing the variation between sites and between months (8). The data used included all months of collection except the two months in which local influences caused biased results. Two missing data were also calculated using the missing data formula. The results indicated that there was a significant difference (5%) between sites but not a highly significant difference. The computed F value was F=2.57 while the rejection values were F=2.28 (5%) and F=3.17 (1%).

The Duncan's MMRT test then was employed to determine which differences were significant, the indication being that the quantity of dust caught at the El Dorado site was significantly different only from the quantity of dust caught in two of the Manhattan surface replicates. There was a highly significant difference between months for this phase of the study (computed F=12.25, rejection F=3.17 at the 1% level). A second analysis of variance was performed after discarding a third month of data, but no change in results was noted.

Graphical representation of the average monthly quantity of dust caught in the four Manhattan surface replicates and the average monthly precipitation at Manhattan indicated that there was apparently little relationship between the two (see Fig. 6). The computed statistical correlation coefficient used all twelve months data (one figure had to be determined through the use of the missing data formula) supplied by the four Manhattan surface replicates, and the recorded average monthly precipitation values at Manhattan, Kansas. The resulting computed value was r =+.148.

Likewise, graphical representation of the average monthly quantity of dust caught in the four Manhattan replicates and the average monthly wind velocity, both at Topeka, and Dodge City, Kansas indicated that there was a weak relationship between the amount of dust at Manhattan and the Topeka wind velocity, while a somewhat better relationship existed between the quantity of dust at Manhattan and the Dodge City wind velocity (see Fig. 7). As above, the computed statistical coefficients used the data determined by the Manhattan surface replicates, and the average monthly wind velocity records supplied by the weather bureau for both Topeka and Dodge City. These values were $r = +.201$ and $r = +.676$ for the Topeka and Dodge City wind velocities, respectively.

Table 1. Monthly deposition of dust at the respective stations for the period August 1965 through November 1966 in lbs./ac. before oxidization.

| Station | Month | Replicates 1 | 2 | 3 | 4 | Ave. | Stand. Deviation |
|---|---|---|---|---|---|---|---|
| Manhattan Surface | Aug. 1965 | 46.2 | 46.3 | 47.2 | 65.4 | 51.3 | 9.43 |
| Manhattan Elevated | Aug. 1965 | 56.3 | | | | 56.3 | |
| Council Grove | Aug. 1965 | 61.1 | | | | 61.1 | |
| El Dorado | Aug. 1965 | No Sample | | | | | |
| Manhattan Surface | Sept.1965 | 29.0 | 26.1 | 28.1 | 27.2 | 27.6 | 1.24 |
| Manhattan Elevated | Sept.1965 | 34.2 | | | | 34.2 | |
| Council Grove | Sept.1965 | 28.8 | | | | 28.8 | |
| El Dorado | Sept.1965 | 27.0 | | | | 27.0 | |
| Manhattan Surface | Oct. 1965 | 14.0 | 13.3 | 12.9 | 16.1 | 14.1 | 1.42 |
| Manhattan Elevated | Oct. 1965 | 15.4 | | | | 15.4 | |
| Council Grove | Oct. 1965 | 15.9 | | | | 15.9 | |
| El Dorado | Oct. 1965 | 13.6 | | | | 13.6 | |
| Manhattan Surface | Nov. 1965 | 14.0 | 12.3 | 10.7 | 12.8 | 12.3 | 1.38 |
| Manhattan Elevated | Nov. 1965 | 13.8 | | | | 13.8 | |
| Council Grove | Nov. 1965 | 10.7 | | | | 10.7 | |
| El Dorado | Nov. 1965 | 11.8 | | | | 11.8 | |
| Manhattan Surface | Dec. 1965 | 8.4 | 7.2 | 7.4 | 6.7 | 7.4 | 0.71 |
| Manhattan Elevated | Dec. 1965 | 12.2 | | | | 12.2 | |
| Council Grove | Dec. 1965 | 9.6 | | | | 9.6 | |
| El Dorado | Dec. 1965 | 8.2 | | | | 8.2 | |

Table 1 (cont.) Monthly deposition of dust at the respective stations for the period August 1965 through November 1966 in lbs./ac. before oxidization.

| Station | Month | Replicates 1 | 2 | 3 | 4 | Ave. | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Manhattan Surface | Jan. 1966 | 7.9 | 6.8 | 8.3 | 8.3 | 7.8 | 0.71 |
| Manhattan Elevated | Jan. 1966 | 10.9 | | | | 10.9 | |
| Council Grove | Jan. 1966 | 6.1 | | | | 6.1 | |
| El Dorado | Jan. 1966 | 5.6 | | | | 5.6 | |
| Manhattan Surface | Feb. 1966 | 6.0 | 5.8 | 4.5 | 5.5 | 5.5 | 0.67 |
| Manhattan Elevated | Feb. 1966 | 9.5 | | | | 9.5 | |
| Council Grove | Feb. 1966 | 12.4 | | | | 12.4 | |
| El Dorado | Feb. 1966 | 4.5 | | | | 4.5 | |
| Manhattan Surface | Mar. 1966 | 44.7 | 39.8 | 46.7 | 78.5 | 43.7 | 20.29 |
| Manhattan Elevated | Mar. 1966 | 18.9 | | | | 18.9 | |
| Council Grove | Mar. 1966 | 139.4[5] | | | | 139.4[5] | |
| El Dorado | Mar. 1966 | 52.3 | | | | 52.3 | |
| Manhattan Surface | Apr. 1966 | 28.2 | 30.4 | 37.7 | Lost | 32.1 | 4.97 |
| Manhattan Elevated | Apr. 1966 | 24.4 | | | | 24.4 | |
| Council Grove | Apr. 1966 | 107.2 | | | | 107.2 | |
| El Dorado | Apr. 1966 | 68.3 | | | | 68.3 | |
| Manhattan Surface | May 1966 | 32.2 | 35.5 | 35.4 | 44.8 | 37.0 | 5.44 |
| Manhattan Elevated | May 1966 | 59.4 | | | | 59.4 | |
| Council Grove | May 1966 | 57.3 | | | | 57.3 | |
| El Dorado | May 1966 | 46.6 | | | | 46.6 | |
| Manhattan Surface | June 1966 | 51.3 | 50.0 | 49.0 | 50.1 | 50.1 | 0.94 |
| Manhattan Elevated | June 1966 | 207.9[6] | | | | 207.9[6] | |
| Council Grove | June 1966 | 54.2 | | | | 54.2 | |
| El Dorado | June 1966 | 35.9 | | | | 35.9 | |
| Manhattan Surface | July 1966 | 31.1 | 27.6 | 28.6 | 30.6 | 29.5 | 1.65 |
| Manhattan Elevated | July 1966 | 103.4 | | | | 103.4 | |
| Council Grove | July 1966 | 27.5 | | | | 27.5 | |
| El Dorado | July 1966 | 95.0 | | | | 95.0 | |
| Manhattan Surface | Aug. 1966 | 24.6 | 23.5 | 25.4 | 23.1 | 24.2 | 1.05 |
| Manhattan Elevated | Aug. 1966 | 37.7 | | | | 37.7 | |
| Council Grove | Aug. 1966 | 30.6 | | | | 30.6 | |
| El Dorado | Aug. 1966 | 72.5 | | | | 72.5 | |

[5] Locally influenced by cattle feeding operations nearby.
[6] Locally influenced by a hawk which used it as a perch.

Table 1 (cont.) Monthly deposition of dust at the respective stations for the period August 1965 through November 1966 in lbs./ac. before oxidization.

| Station | Month | Replicates 1 | 2 | 3 | 4 | Ave. | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Manhattan Surface | Sept. 1966 | 30.3 | 30.5 | 29.8 | 29.4 | 30.0 | 0.50 |
| Manhattan Elevated | Sept. 1966 | 26.5 | | | | 26.5 | |
| Manhattan Surface | Oct. 1966 | 39.7 | 34.9 | 27.0 | 32.7 | 29.2 | 7.30 |
| Manhattan Elevated | Oct. 1966 | 17.6 | | | | 17.6 | |
| Manhattan Surface | Nov. 1966 | 13.1 | 14.8 | 12.9 | 13.9 | 13.7 | 0.87 |
| Manhattan Elevated | Nov. 1966 | 15.0 | | | | 15.0 | |
| Manhattan Surface #1 | Mean Monthly (16 months) | | | | | 26.29 | |
| Manhattan Surface #2 | Mean Monthly (16 months) | | | | | 25.30 | |
| Manhattan Surface #3 | Mean Monthly (16 months) | | | | | 25.73 | |
| Manhattan Surface #4 | Mean Monthly (16 months) | | | | | 29.67 | |
| Manhattan Elevated | Mean Monthly (16 months) | | | | | 41.44 | |
| Council Grove | Mean Monthly (13 months) | | | | | 43.14 | |
| El Dorado | Mean Monthly (12 months) | | | | | 36.78 | |

The total amount of dust falling from the atmosphere during the year August 1965 through July 1966 is somewhat difficult to state with absolute precision due to local contaminating influences. However, using one of the Manhattan replicates which was not considered to be greatly affected by local influences, the total annual dust fall amounted to 313 pounds per acre. This is an average of 26.08 pounds per acre per month and would require 3,195 years to build an acre-furrow-slice of soil at this rate.

## Mineralogy of Dust

The dominant minerals contained in the dust that settled from the atmosphere as determined through the use of the petrographic microscope, included quartz, opal phytoliths, calcite, and clay and iron stained aggregates (see Table 2). Traces of other minerals which were often present included

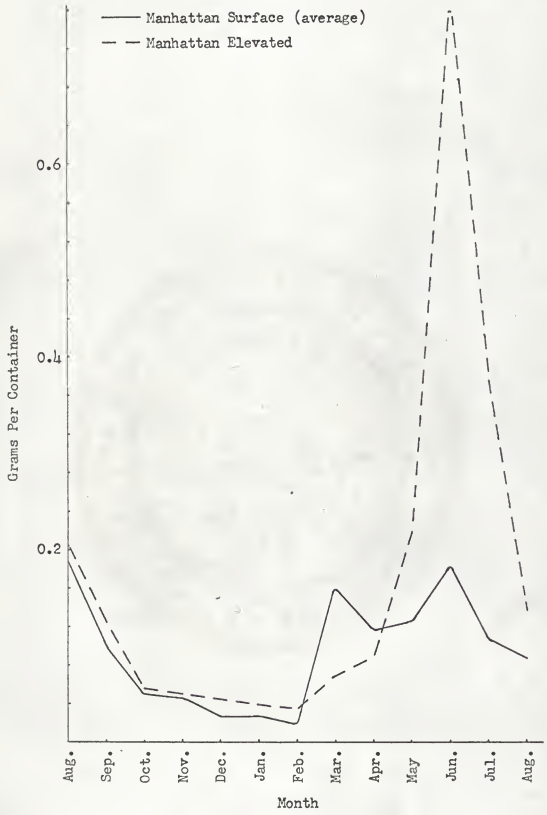


Fig. 5. A comparison of the rates of dust deposition between the elevated container and the average of the surface containers at the Manhattan site for the period August 1965 through August 1966. The June and July 1966 elevated container figures are biased by bird droppings.

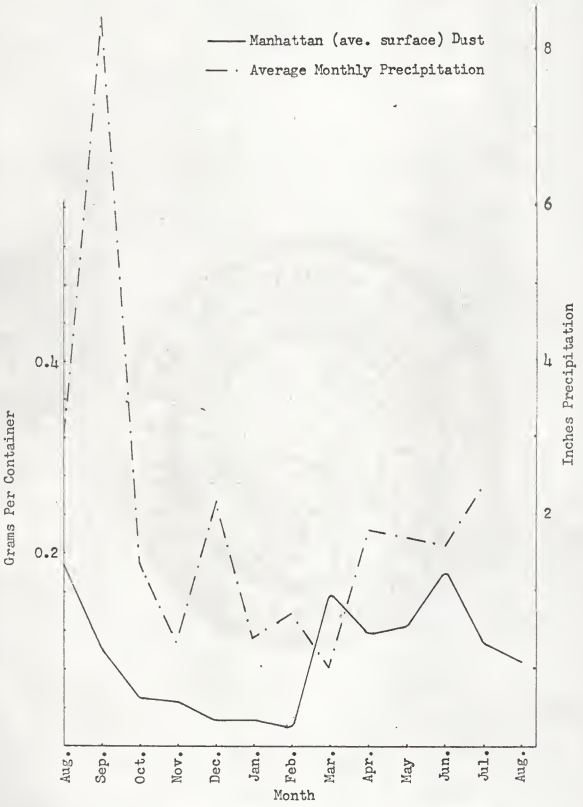


Fig. 6. Graphical representation of the relationship between the rate of dust deposition into the surface containers (average) at Manhattan, and the average monthly precipitation at Manhattan Kansas.

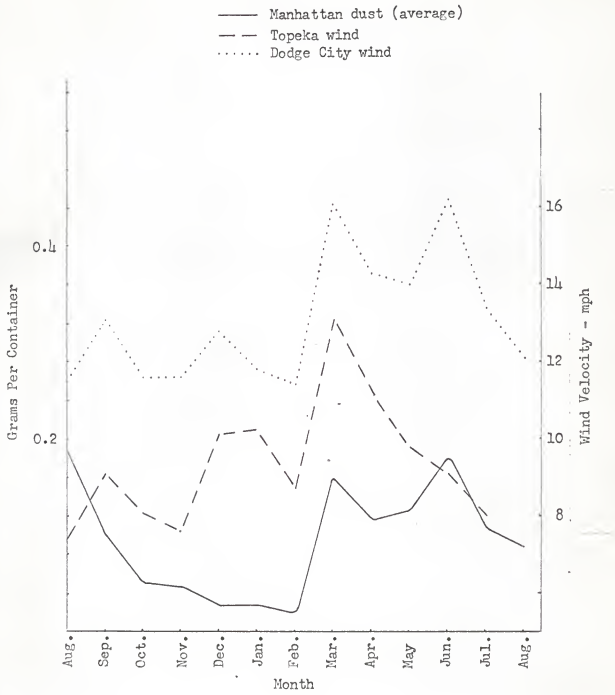


Fig. 7. Graphical representation of the relationship between the rate of dust deposition into the surface containers (average) at Manhattan, and the average monthly wind velocities at Topeka and Dodge City, Kansas.

hematite, hornblende , zircon, tourmaline, plagioclase, microcline, orthoclase and biotite. Unidentifiable minerals were present only in isolated cases.

From all indications, there did not appear to be any trend, seasonal influence, site influence, or other outstanding characteristic emerge from these data with the exception of the elevated container which consistently yielded a higher percentage of aggregated material. Different sites for the same month often yielded contrasting percentage results for the same mineral. For example, the January, 1966 samples from the Manhattan surface containers yielded dust with 87.6% quartz, the Council Grove sample contained 59.2% quartz and the El Dorado sample only 10.7% quartz. This mineral percentage heterogeneity persisted over the entire period of study for most of the minerals present in the dust. The Council Grove and El Dorado sites for February, 1966 contained mostly material of an unidentifiable nature, believed to be organic. This material consisted of large isotropic plate-like particles to which all the mineral particles adhered. It is unknown at this time what this material was or from where it came.

The percentages of sand and silt, like the dominant minerals present, were quite varied in monthly amounts and did not appear to follow any characteristic trends. There is a possibility of a seasonal decrease in percentage of sand- and silt-sized minerals in May, June and July (See Fig. 8). Although this is a graph of the percentage of clays present the sand and silt fraction make up the remainder of the dust sample to 100%, or is equal to 100 minus the percentage of clays shown. The maximum percentage of sand and silt occurred in April at the El Dorado site with 85.4% while the minimum occurred in July at the Manhattan elevated site with 31.4%.

The percentage of clay, or that part of the sample not consisting of sand- and silt-sized particles, is represented graphically in Fig. 8. The highest percentage of clays occurred in July in the elevated conatiner with 68.6%

Table 2. Volume percentages of dominant minerals present in the sand and silt fraction of dust samples from August 1965 through July 1966.

| | | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manhattan (Surface) | Quartz | 57.4 | 68.7 | 83.9 | 55.1 | 91.3 | 87.6 | 92.4 | 78.7 | 95.8 | 91.7 | 55.6 | 91.3 | 79.1 |
| | Phytoliths | 27.0 | 19.6 | 1.1 | 32.3 | 2.1 | 5.4 | 4.0 | 9.0 | 1.1 | 5.2 | 10.9 | 5.8 | 10.3 |
| | Calcite | 1.2 | 2.5 | 0.2 | 0.4 | 1.1 | 1.2 | 0.1 | 0.5 | 0.2 | 0.0 | 0.1 | 0.0 | 0.75 |
| | Aggregates (clay) | 3.5 | 4.5 | 4.8 | 5.0 | 1.3 | 0.7 | 0.4 | 8.1 | 2.0 | 1.6 | 2.4 | 0.3 | 2.9 |
| | (iron stained) | 7.2 | 4.3 | 9.8 | 6.8 | 3.9 | 4.4 | 3.1 | 3.8 | 0.7 | 1.3 | 30.9 | 2.3 | 6.5 |
| Manhattan (Elevated) | Quartz | 7.5 | 30.7 | 27.5 | 5.7 | 36.7 | 61.5 | 47.3 | 71.2 | 92.9 | 84.5 | 28.9 | 21.9 | 43.0 |
| | Phytoliths | 0.0 | 3.2 | 3.2 | 0.0 | 0.8 | 0.0 | 0.8 | 21.3 | 0.6 | 2.2 | 1.1 | 0.8 | 3.8 |
| | Calcite | 0.0 | 0.3 | 0.3 | 5.3 | 0.9 | 0.2 | 0.6 | 1.5 | 0.1 | 0.0 | 8.9 | 0.1 | 1.8 |
| | Aggregates (clay) | 49.4 | 38.7 | 11.6 | 35.7 | 30.4 | 18.7 | 0.1 | 0.9 | 2.4 | 2.9 | 15.0 | 2.0 | 17.3 |
| | (iron stained) | 42.9 | 27.1 | 57.2 | 53.2 | 31.0 | 19.4 | 51.3 | 2.3 | 3.7 | 8.3 | 45.8 | 74.8 | 34.75 |
| Council Grove | Quartz | 85.9 | 51.6 | 82.0 | 66.7 | 56.5 | 59.2 | * | 82.6 | 78.2 | 92.6 | 84.6 | 78.3 | 74.4 |
| | Phytoliths | 0.8 | 13.3 | 3.9 | 6.0 | 3.9 | 1.0 | | 11.8 | 0.2 | 4.3 | 13.3 | 17.2 | 6.9 |
| | Calcite | 0.1 | 0.3 | 0.4 | 1.7 | 0.6 | 1.2 | | 1.5 | 0.1 | 0.1 | 0.1 | 0.8 | 0.6 |
| | Aggregates (clay) | 12.2 | 10.0 | 2.1 | 12.7 | 20.1 | 32.8 | | 1.6 | 0.7 | 1.4 | 1.5 | 0.6 | 8.7 |
| | (iron stained) | 1.0 | 24.6 | 11.0 | 12.4 | 18.6 | 5.2 | | 2.1 | 19.9 | 1.5 | 0.2 | 2.2 | 9.0 |
| El Dorado | Quartz | | 50.2 | 24.6 | 94.2 | 82.6 | 10.7 | * | 95.0 | 89.4 | 75.7 | 82.6 | 81.1 | 68.6 |
| | Phytoliths | | 18.3 | 2.0 | 2.2 | 2.7 | 0.0 | | 2.6 | 0.8 | 1.4 | 12.4 | 17.1 | 6.6 |
| | Calcite | | 0.4 | 0.2 | 0.4 | 0.1 | 0.0 | | 0.0 | 0.5 | 0.1 | 0.2 | 0.2 | 0.3 |
| | Aggregates (clay) | | 14.5 | 40.5 | 2.4 | 8.3 | 88.9 | | 0.5 | 1.9 | 0.1 | 0.4 | 0.5 | 15.8 |
| | (iron stained) | | 15.8 | 32.2 | 0.7 | 6.2 | 0.2 | | 1.7 | 6.7 | 22.5 | 4.3 | 1.1 | 9.1 |

* Large, flaky appearing granules probably of organic nature.

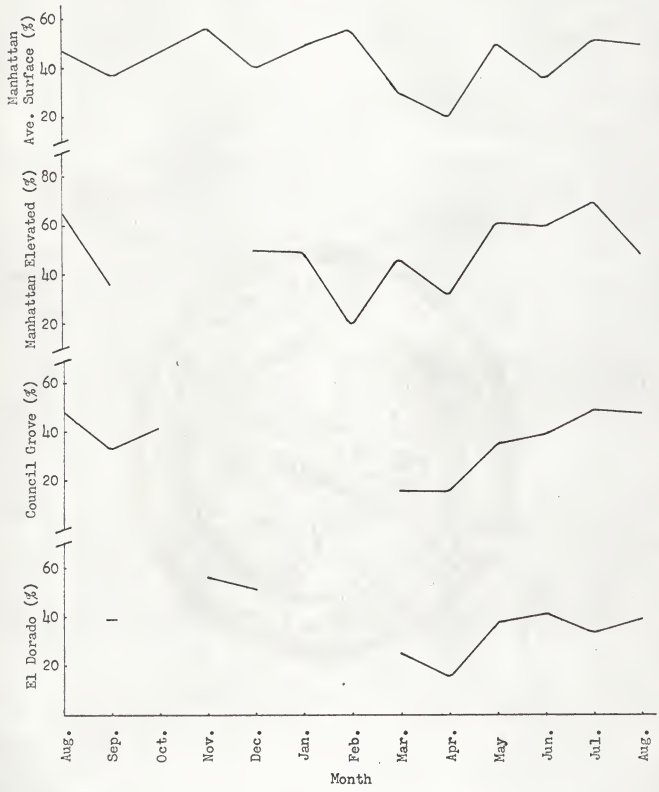


Fig. 8. Percent clay present in the monthly dust samples at the respective stations.

while the lowest percentage occurred in April at the El Dorado site with 14.6%. As seen in the tables of the X-ray diffractograms,[7] some months had little or no identifiable clay patterns even though there was clay-sized material in the dust sample (see Fig. 9 through 21). Most months yielded distinctively identifiable clay patterns with illite nearly always present, and most often in greatest abundance. Kaolinite was also commonly present and in second greatest abundance, quartz and feldspar minerals were nearly always present in small amounts, montmorillonite and/or chlorite also was frequently present but also in small amounts. The months with the smallest amounts of identifiable clays included August and September of 1965 and April of 1966.

One of the replicates at the Manhattan site was collected twice in March to check the possibility of verifying the origin of the dust reportedly originating in New Mexico to determine if it was different mineralogically from that for the rest of the month. The sand and silt fraction displayed no identifiable differences, however the clay fraction appeared to have much less montmorillonite in the first collection (New Mexico dust) than in the dust for the remainder of the month. The remaining replicates (excepting the elevated container) as well as the other two sites, yielded a greater amount of montmorillonite clays for this month than for any other month in the study. The elevated container sample contained only a small amount of montmorillonite clays for this month.

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[7] The faint handwritten description above the peaks on each of the diffractograms is not essential for the identification of the peaks in this manuscript and should be disregarded. The peaks are identified properly by the bold face type along either the left or the bottom edge of the left or bottom diffractogram. Also, the glycolated pattern is the left end extension of each of the regular patterns.

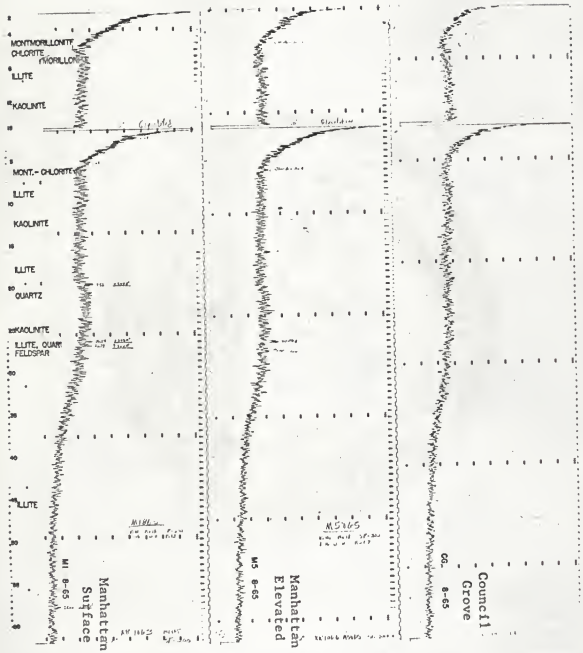



Fig. 9. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for August 1965 at the listed sites.

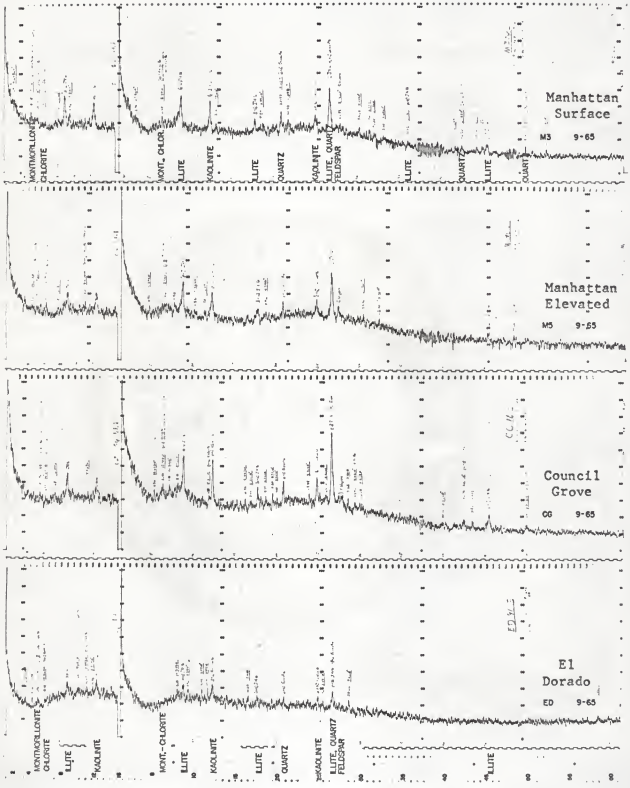



Fig. 10. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for September 1965 at the listed sites.

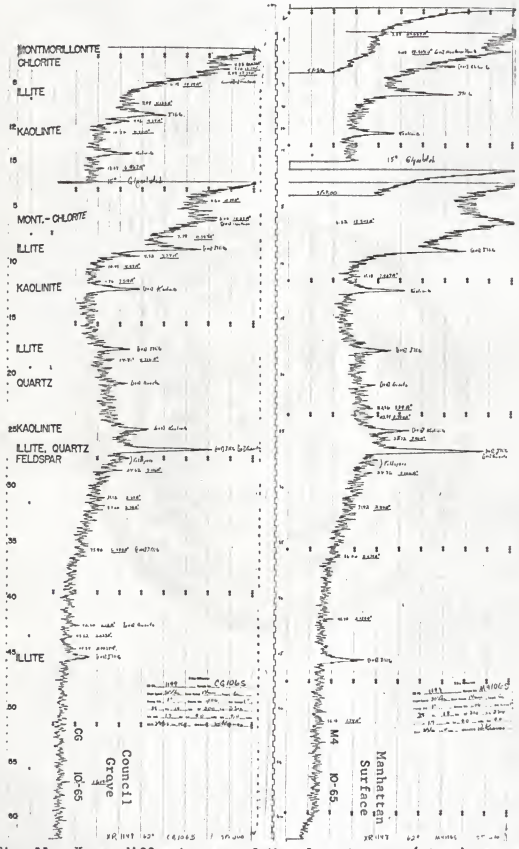



Fig. 11. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for October 1965 at the listed sites.


Fig. 12. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for November 1965 at the listed site.


Fig. 13. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for December 1965 at the listed sites.

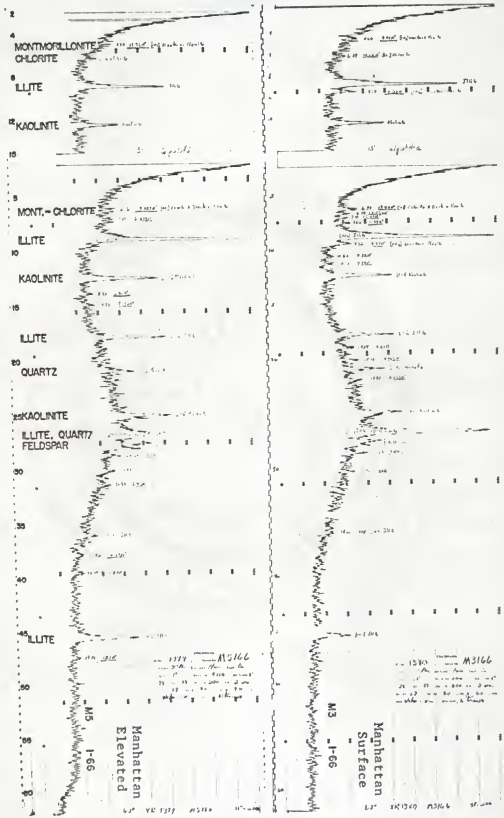



Fig. 14. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for January 1966 at the listed sites.

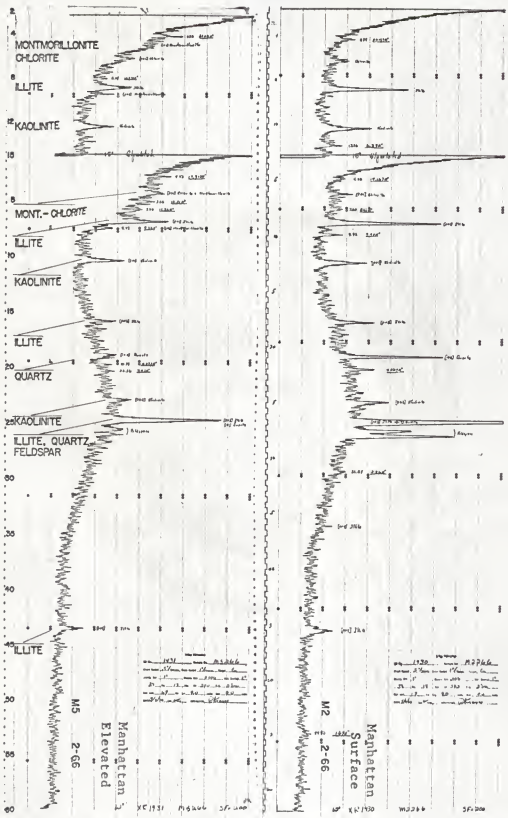



Fig. 15. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for February 1966 at the listed sites.

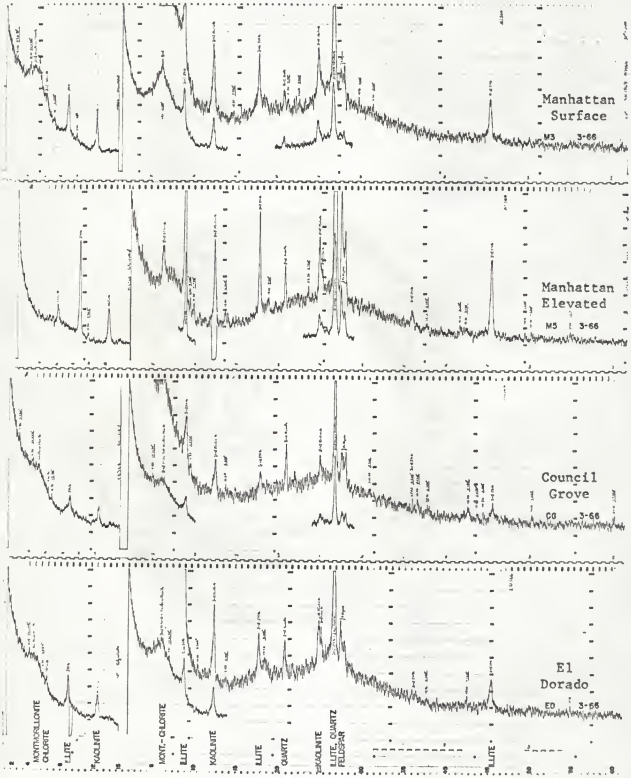



Fig. 16. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for March 1966 at the listed sites.

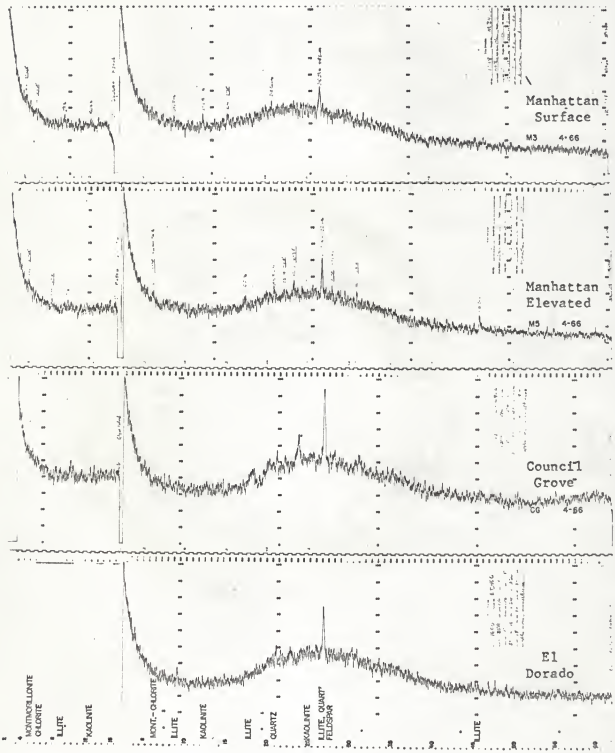



Fig. 17. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for April 1966 at the listed sites.

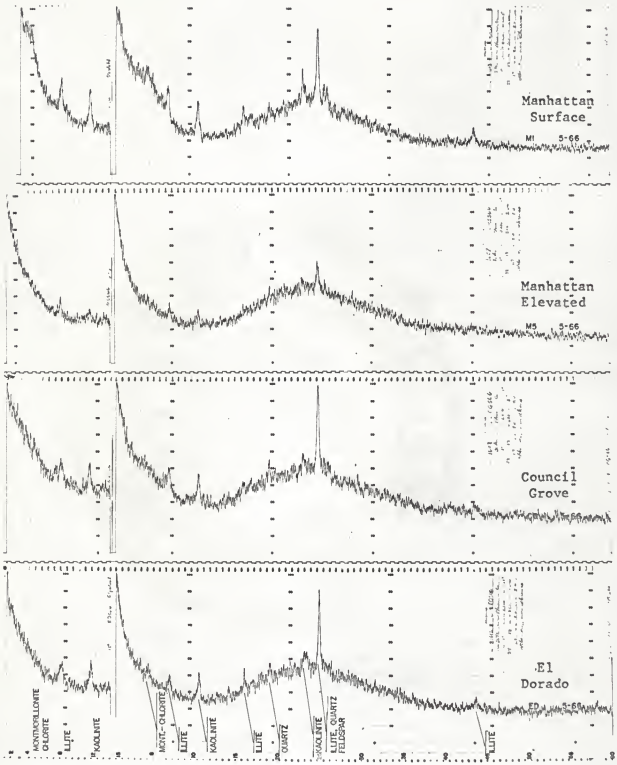



Fig. 18. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for May 1966 at the listed sites.

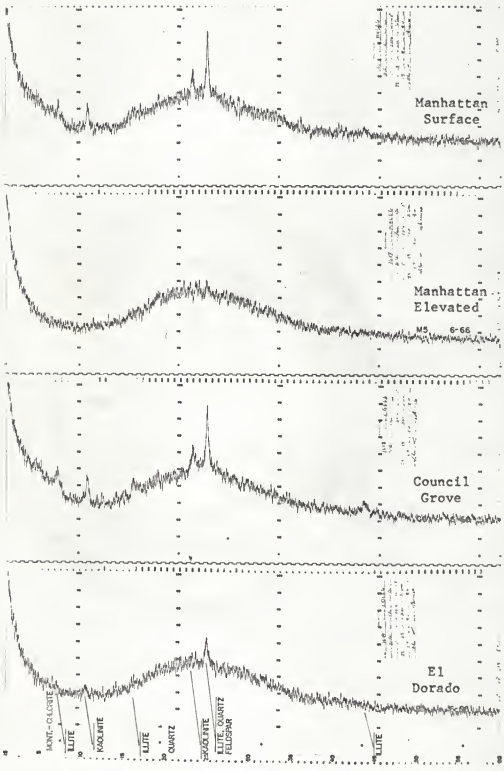



Fig. 19. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for June 1966 at the listed sites.

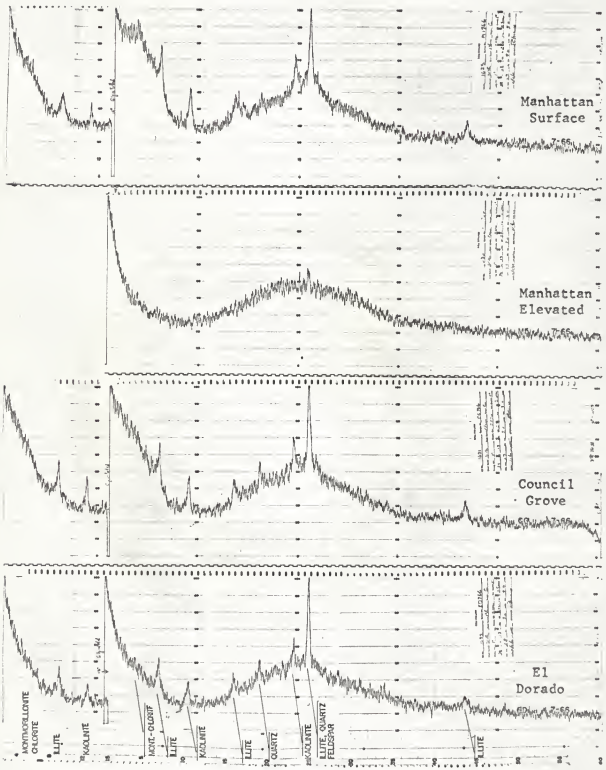



Fig. 20. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for July 1966 at the listed sites.

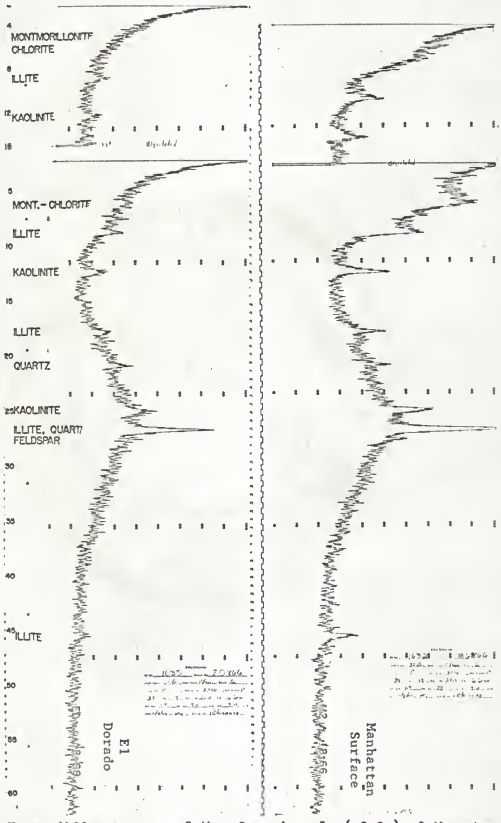



Fig. 21. X-ray diffractograms of the clay minerals (<2.0u) of the atmospheric dust for August 1966 at the listed sites.

## Mineralogy of Soils

The mineralogy of the soils collected at the sites was all uniform in kind and amount of different minerals present. The dominant mineral was quartz, and, with the exception of the surface one-half inch of soil, the percentage of quartz was always above 90%. The lowest percentage of quartz was at the Manhattan site where the upper one-half inch of soil contained only 79.9%, while the highest percent quartz was at the 1/2 to 1 inch depth at the El Dorado site. Small grains of chert were also present but were included in the quartz fraction. Other dominant minerals included opal phytoliths and clay and iron stained aggregates (see Table 3). Minor or trace amounts of calcite, hematite, zircon, tourmaline, microcline, plagioclase, biotite, orthoclase, and other minerals were commonly present. An interesting aspect emerged in this microscopic study with two of the minerals--microcline and orthoclase. It was found that these minerals were commonly present especially microcline in the greatest abundance, the largest size, and the greatest angularity in the upper 1/2 inch of soil (see Plate 2). Progressing downward through the soil horizon, these minerals became less angular or more rounded, smaller in size, and more difficult to identify, undoubtedly due to weathering processes. Itwas also found that these minerals were commonly present in the dust samples where they were among the largest minerals present, and quite fresh though sometimes slightly rounded.

The percentage of sand and silt in the samples were relatively uniform at each site but quite varied between sites. At the Manhattan site, the percentage of sand and silt from the soil sample ranged from a high of 52.1% in the surface 1/2 inch of soil to a low of 48.1% at the 5-inch depth. The Council Grove site yielded a maximum of 72.4% and a minimum of 69.0% sand and silt in

Table 3 . Percentages of dominant minerals present in the sand and silt fraction of soil samples from the surface down to a depth of five inches.

| | | Inches in Depth | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0.0-0.5 | 0.5-1.0 | 1.0-1.5 | 1.5-2.0 | 2.0-3.0 | 3.0-4.0 | 4.0-5.0 |
| Manhattan | Quartz | 79.9 | 96.1 | 99.1 | 97.1 | 95.7 | 94.2 | 96.2 |
| | Phytoliths | 4.7 | 3.5 | 0.7 | 2.1 | 3.9 | 5.8 | 2.5 |
| | Calcite | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 |
| | Aggregates (clay) | 15.3 | 0.4 | 0.0 | 0.4 | 0.3 | 0.0 | 0.2 |
| | (iron stained) | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Council Grove | Quartz | 88.1 | 99.0 | 95.5 | 97.3 | 97.8 | 92.8 | 95.5 |
| | Phytoliths | 2.6 | 0.9 | 2.2 | 0.8 | 0.7 | 4.3 | 3.6 |
| | Calcite | 0.4 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| | Aggregates (clay) | 4.1 | 0.1 | 1.1 | 0.9 | 0.7 | 1.4 | 0.6 |
| | (iron stained) | 4.6 | 0.0 | 1.0 | 0.7 | 0.7 | 1.4 | 0.2 |
| El Dorado | Quartz | 90.8 | 99.5 | 96.3 | 97.1 | 90.0 | 96.0 | 97.0 |
| | Phytoliths | 2.5 | 0.2 | 1.9 | 0.7 | 1.0 | 2.0 | 0.6 |
| | Calcite | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Aggregates (clay) | 1.5 | 0.2 | 0.2 | 1.0 | 2.0 | 0.6 | 0.2 |
| | (iron stained) | 5.1 | 0.0 | 1.4 | 1.0 | 7.0 | 1.3 | 1.9 |

its soil sample while the El Dorado site yielded a maximum and a minimum of 80.4% (1/2 to 1 inch depth) and 78.3% (4 to 5 inch depth), respectively. The clay percentages make up the remainder of the sample to 100% (see Tables 4 and 5).

Table 4. The percent sand-and silt-sized fraction of the Florence soils sampled at various depths.

| Depth | Site | | |
|---|---|---|---|
| | Manhattan | Council Grove | El Dorado |
| in. | % | % | % |
| 0.0-0.5 | 52 | 72 | 80 |
| 0.5-1.0 | 51 | 70 | 80 |
| 1.0-1.5 | 51 | 70 | 79 |
| 1.5-2.0 | 51 | 70 | 80 |
| 2.0-3.0 | 50 | 69 | 79 |
| 3.0-4.0 | 50 | 69 | 79 |
| 4.0-5.0 | 48 | 70 | 78 |

The soil clays in this study were fractionated into coarse, medium and fine clays to determine the amounts of each clay size fraction at each different depth in the horizon, and the dominant clays in each size fraction. These data are listed in Table 5 with basically the following results. The greatest percentage of all the clays was the fine-sized fraction (less than .08 micron), in which the predominant clay was montmorillonite. The least abundant clay fraction was the medium-sized fraction at the Council Grove and El Dorado sites and the coarse-sized fraction at the Manhattan site. The reason for this discrepency is not understood at this time but the dominant clays were illite followed very closely by kaolinite. Very little or no montmorillonite was present in the coarse fraction (2.0 to 0.2 microns), while small amounts of this clay did begin to appear in the medium-size fraction (0.2 to 0.08 microns). Because the X-ray diffractograms are quite similar between sites, only reproductions of those for one soil, that at Manhattan, will be enclosed here (see Figs. 22 through 28).

Table 5. Kinds, weight percentages, and relative amounts of clays of different-sized fractions in the Florence soils as determined by X-ray diffraction.

| Site | Depth (in.) | Clays | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coarse* | | | | | Medium* | | | | | Fine* | | | | |
| | | % | | | | | % | | | | | % | | | | |
| | | % | Illite | Kaolinite | Montmorillinite | Quartz | % | Illite | Kaolinite | Montmorillinite | Quartz | % | Illite | Kaolinite | Montmorillinite | Quartz |
| Manhattan | 0-½ | 16.6 | 4 | | | 3 | 21.8 | 3 | 3 | 2 | 1 | 47.7 | 2 | 2 | 4 | |
| | ½-1 | 16.4 | 4 | 1 | | 3 | 21.0 | 4 | 3 | 1 | | 52.9 | 2 | 2 | 4 | |
| | 1-1½ | 16.0 | 4 | 1 | | 3 | 20.9 | 4 | 3 | 1 | 1 | 52.8 | 2 | 2 | 4 | |
| | 1½-2 | 15.7 | 4 | 1 | | 3 | 22.4 | 4 | 3 | 1 | 1 | 54.2 | 2 | 2 | 4 | |
| | 2-3 | 15.6 | 4 | 2 | 1 | 3 | 21.2 | 4 | 3 | 1 | 1 | 54.0 | 2 | 1 | 4 | |
| | 3-4 | 15.6 | 4 | 2 | | 3 | 22.0 | 4 | 3 | 1 | 1 | 54.7 | 2 | 1 | 4 | |
| | 4-5 | 15.0 | 4 | 2 | | 3 | 21.9 | 4 | 3 | 1 | 1 | 57.7 | 2 | 2 | 4 | |
| Council Grove | 0-½ | 26.2 | 3 | 2 | 1 | 3 | 20.0 | 3 | 3 | 2 | | 41.7 | 2 | 1 | 4 | |
| | ½-1 | 25.2 | 3 | 2 | | 3 | 20.1 | 3 | 3 | 2 | 1 | 42.6 | 2 | 1 | 4 | |
| | 1-1½ | 24.9 | 3 | 2 | 1 | 3 | 19.5 | 3 | 3 | 2 | 1 | 45.9 | 2 | 1 | 4 | |
| | 1½-2 | 25.8 | 3 | 2 | 1 | 3 | 19.5 | 3 | 3 | 2 | 2 | 47.5 | 2 | 1 | 4 | |
| | 2-3 | 25.2 | 3 | 2 | | 3 | 19.4 | 3 | 3 | 2 | 1 | 46.5 | 2 | 1 | 4 | |
| | 3-4 | 24.1 | 3 | 2 | | 3 | 19.5 | 3 | 3 | 2 | | 48.8 | 2 | 1 | 4 | |
| | 4-5 | 24.4 | 3 | 2 | | 3 | 19.5 | 3 | 3 | 2 | 1 | 47.5 | 2 | 1 | 4 | |
| El Dorado | 0-½ | 28.0 | 3 | 2 | | 3 | 23.5 | 3 | 2 | 2 | 1 | 34.3 | 3 | 1 | 4 | |
| | ½-1 | 27.5 | 3 | 2 | | 3 | 21.6 | 3 | 2 | 2 | 1 | 40.1 | 2 | 2 | 4 | |
| | 1-1½ | 27.7 | 3 | 2 | | 3 | 19.9 | 3 | 3 | 1 | 1 | 35.7 | 2 | 2 | 4 | |
| | 1½-2 | 29.1 | 3 | 2 | | 3 | 19.1 | 3 | 3 | 1 | 1 | 13.1 | 2 | 1 | 4 | |
| | 2-3 | 26.4 | 3 | 2 | | 3 | 18.7 | 3 | 3 | 2 | 1 | 34.2 | 2 | 2 | 4 | |
| | 3-4 | 27.4 | 3 | 2 | | 3 | 18.1 | 3 | 3 | 1 | | 37.2 | 3 | 2 | 4 | |
| | 4-5 | 26.0 | 3 | 2 | | 3 | 17.0 | 3 | 3 | 1 | 1 | 36.5 | 3 | 2 | 4 | |

* Coded concentrations whereby 1 = <10%, 2 = 10-25%, 3 = 25-50%, 4 = 50-75% and 5 = >75% of the size fraction.

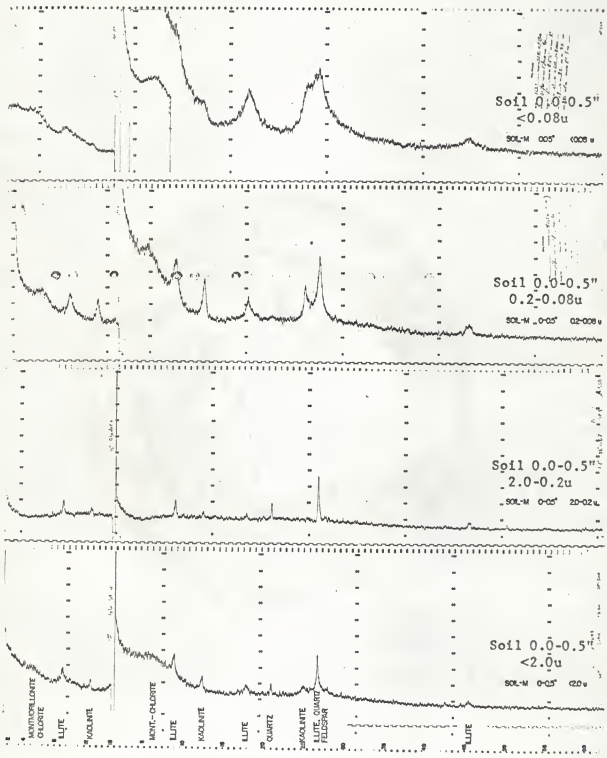



Fig. 22. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 0.0 to 0.5 inch depth.

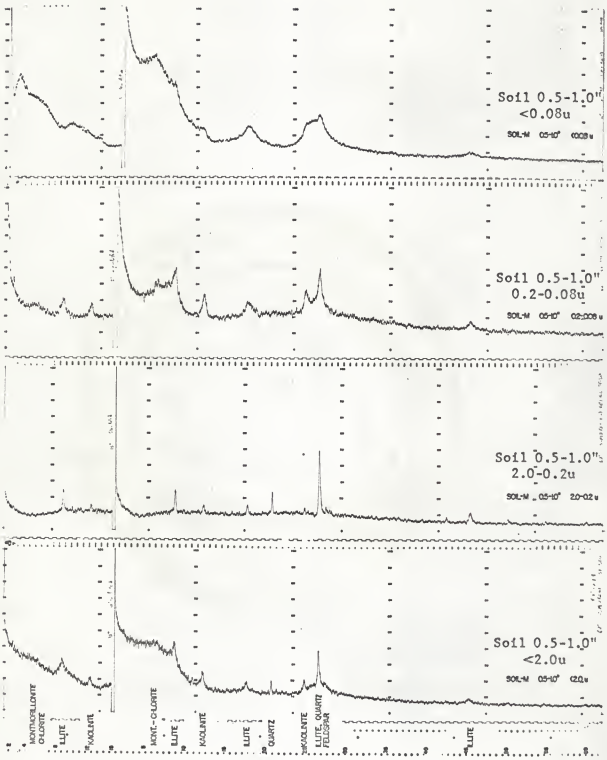



Fig. 23. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 0.5 to 1.0 inch depth.

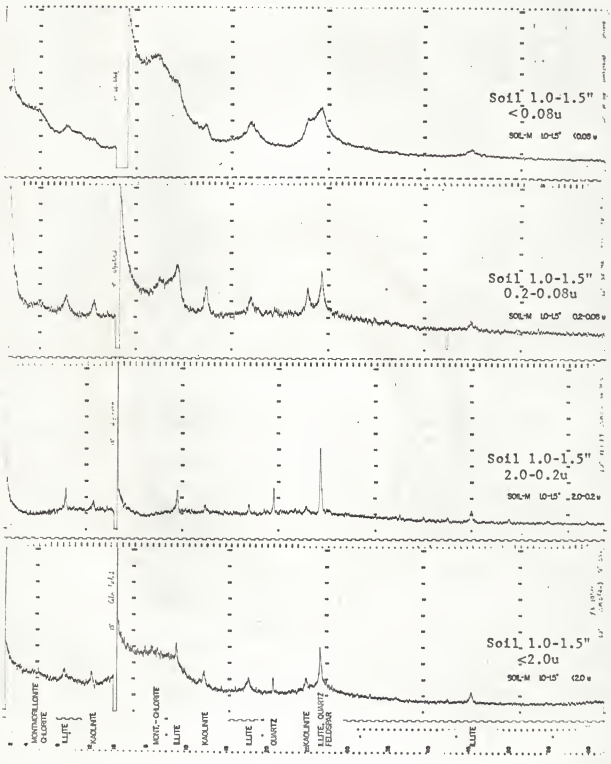



Fig. 24. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 1.0 to 1.5 inch depth.

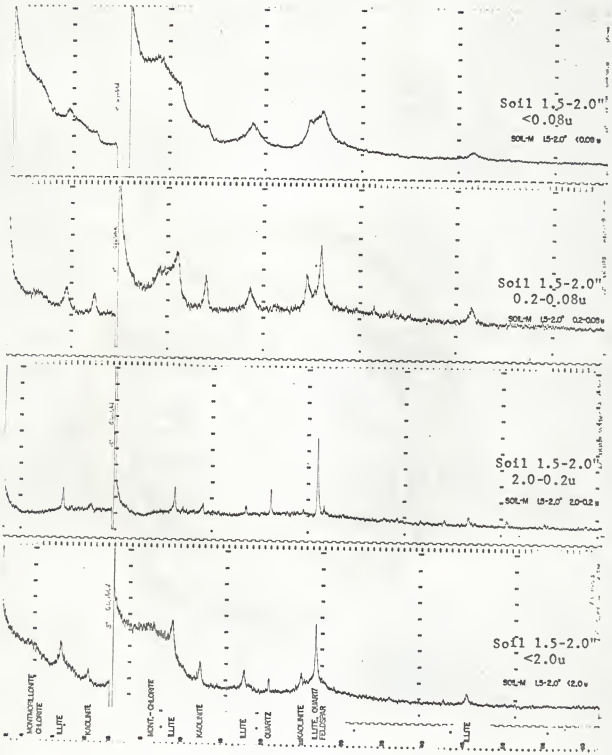



Fig. 25. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 1.5 to 2.0 inch depth.

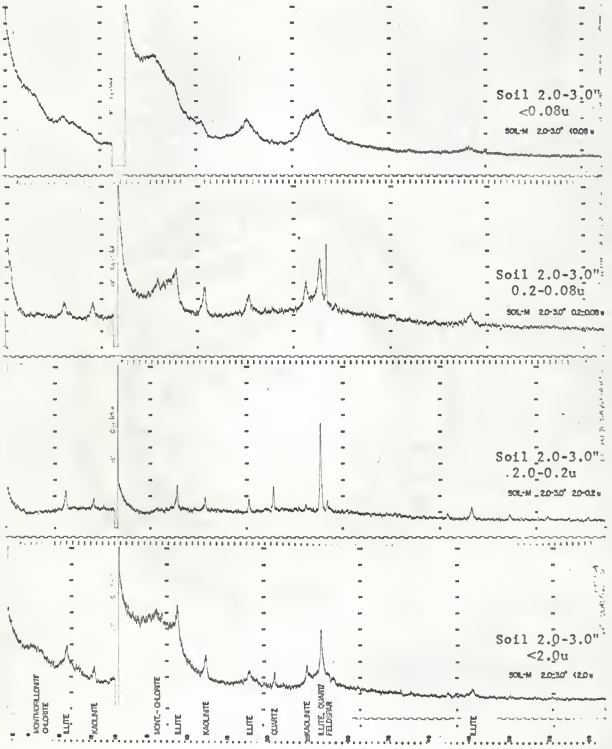



Fig. 26. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 2.0 to 3.0 inch depth.

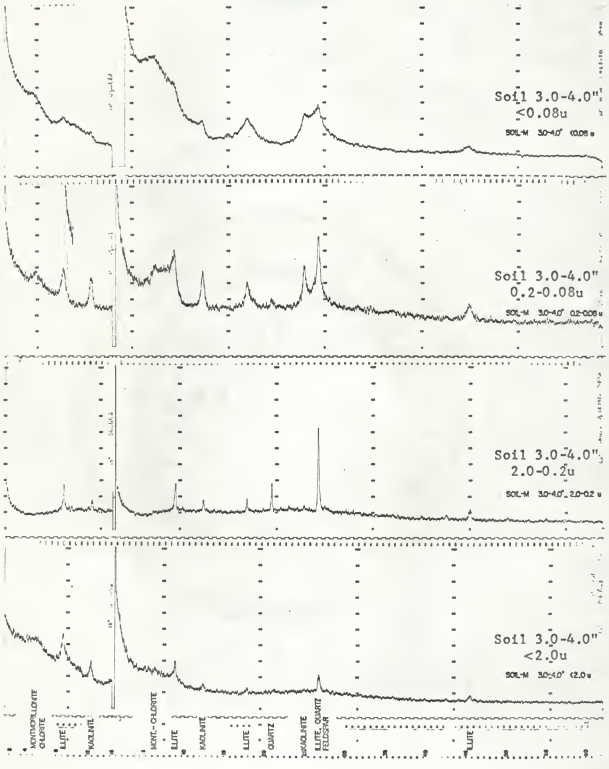



Fig. 27. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 3.0 to 4.0 inch depth.

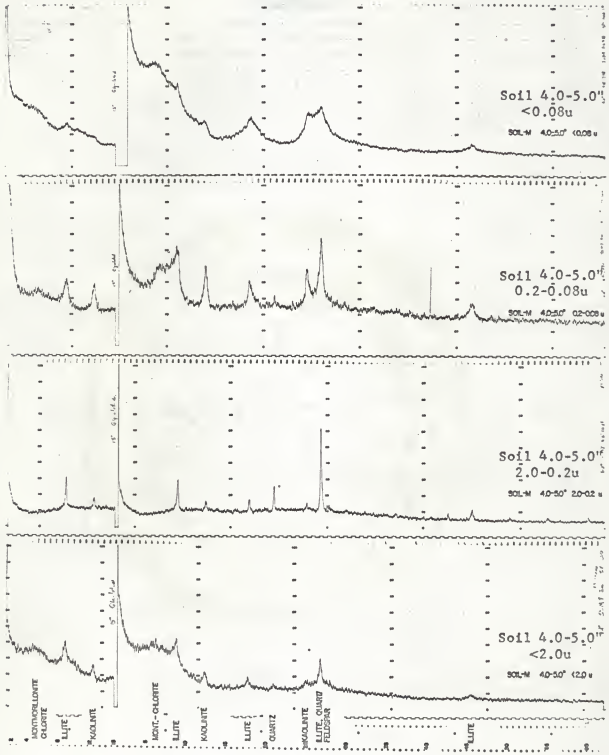



Fig. 28. X-ray diffractograms of the different size clay minerals of the Florence soil (Manhattan site) at the 4.0 to 5.0 inch depth.

## Chemical Properties of Dust

The pH of the dust that settled from the atmosphere was quite high when this study was initiated, being around 8.0. It then decreased rapidly to slightly over 6.0 in November 1965, generally increased then to about 7.4 in April 1966, decreased suddenly again to about 6.0 in May and June 1966, and finally began a slight upward trend the last two months (see Fig. 29). Because all the sites reflected so nearly the same seasonal trend, the pH's were all averaged in this graph. The greatest difference in pH between sites occurred in March when the El Dorado site had a low pH of 5.4 and the Manhattan and Council Grove sites had the higher pH of 6.4. The greatest difference in pH of the replicates at the Manhattan site was also in March with a difference of 1.4 pH (6.4 to 7.8).

A statistical analysis-of-variance was performed, testing the variation of the pH of the dust between sites and between months. The results indicate that there was no significant difference between sites (computed F = 2.00, rejection F = 2.28 at the 5% level) while a highly significant difference between months (computed F = 19.44, rejection F = 2.63 at the 1% level) existed.

The percentage of the dust which was oxidizable with 30% hydrogen peroxide was quite variable over the year being highest in late fall and early winter. Following this high, the percentage decreased again to a reasonably uniform value which was maintained, with some fairly wide monthly deviation throughout the remainder of the study (see Fig. 30). The variation between the surface containers and the elevated container at the Manhattan site appeared to be slightly more conflicting in the results obtained than did the deviation among the three surface sites (see Fig. 32). The results among these sites were all reasonably uniform with the exception of the El Dorado sample for April, 1966.

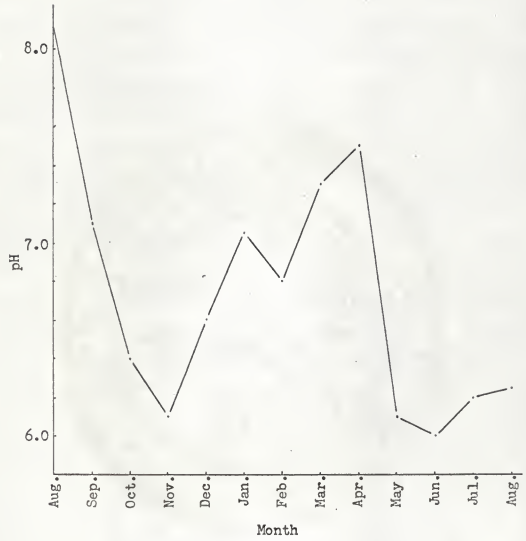



Fig. 29. The average pH of the dust caught at all three sites--Manhattan, Council Grove, and El Dorado--for the period August, 1965 through August, 1966.

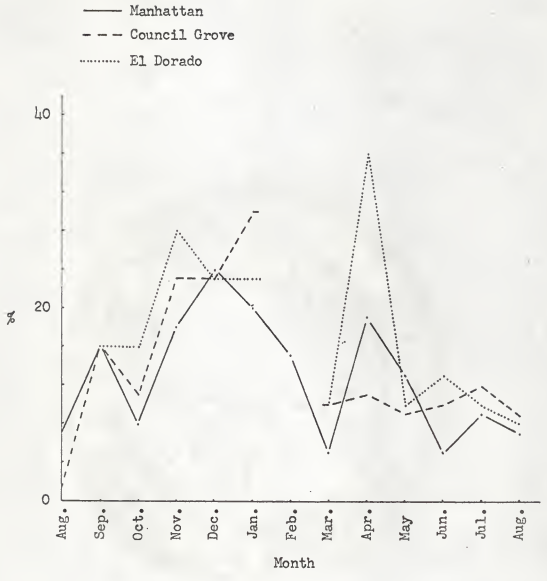



Fig. 30. The percent oxidizable material of dust, August, 1965 through August, 1966.

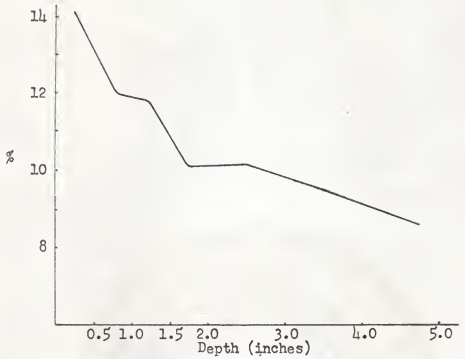



Fig. 31. The percent oxidizable material of the Manhattan soil at the indicated depth.

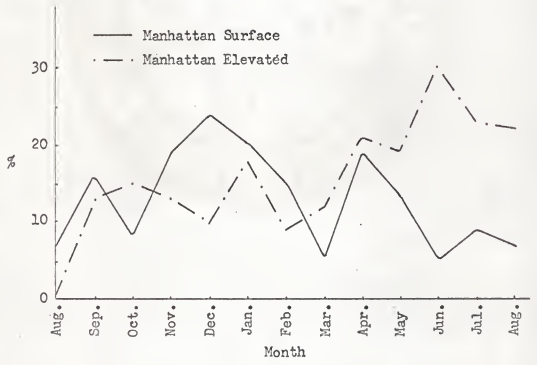



Fig. 32. The percent oxidizable material of dust, August, 1965 through August, 1966.

Although some deviation in the percentage of oxidizable material did occur, the general trend for the period of study was about the same for all sites.

A statistical analysis-of-variance was again performed testing the variation of the oxidizable material of the dust between sites and between months. The results indicate that there was no significant difference between sites (computed F = 1.16, rejection F = 2.27 at the 5% level) while a highly significant difference between months (computed F = 5.10, rejection F= 2.54 at the 1% level) existed.

Before processing for mineralogical study, the September 1966 samples from the four Manhattan surface replicates were combined into one sample, and both it and the Manhattan elevated sample for the same month were processed with 1.0 normal ammonium acetate to extract the exchangeable cations. Identical procedures were performed on the January, 1967 samples. The quantities of the three cations Ca, Mg, and K, then were determined through the use of the atomic absorption meter or the flame photometer. The milliequivalents per 100 grams of dust for these four samples are given in Table 6.

Table 6. Me of Ca, Mg, and K, per 100 grams of atmospheric dust for the months September, 1966 and January, 1967.

| | Milliequivalents per 100 grams | | |
|---|---|---|---|
| | Ca | Mg | K |
| September Surface | 47.6 | 14.7 | 18.9 |
| September Elevated | 50.2 | 16.8 | 11.5 |
| January Surface | 34.4 | 3.9 | Trace |
| January Elevated | 30.3 | 4.9 | Trace |

These data indicated the September dust sample contained 2 to 6 times as much Ca, 2 to 7 times as much Mg and 9 to 20 times as much K as the soils (see Table 8). The January dust samples contained 1½ to 4 times as much Ca, 1/2 to 2 times as much Mg, and much less K than the soils. The only known difference in

procedure included the addition of ethylene glycol to the water of the January sample to eliminate freezing. It is felt by all personnel concerned with this study that the values obtained from the September, 1966 samples, especially for K, are abnormally high and may reflect some unusual pecularity or error. More data and results concerned with this phase of the study are forthcoming.

Samples of the water in the containers from each of the three sites as well as the elevated container were collected and sent to the Greentown Laboratories of W. R. Grace and Co., Atlantic, Iowa, for chemical analyses. The results are given in Table 7.

Table 7. Pounds per acre of the different cations present in the solution analysis tests of the atmospheric dust for August 1966.

| | Pounds Per Acre | | | | |
|---|---|---|---|---|---|
| | Ca | Mg | K | P | Na |
| Manhattan Surface | 0.72 | 0.15 | 0.15 | <0.10 | 0.72 |
| Manhattan Elevated | 1.50 | 0.91 | 0.68 | <0.10 | 9.34 |
| Council Grove | 1.65 | 0.60 | 0.60 | <0.10 | 6.00 |
| El Dorado | 1.32 | <0.12 | 0.72 | <0.10 | 2.40 |

These data are fairly uniform (except sodium) between sites but variable between cations, and although low in concentration for phosphorous, may, by future refinement with more months of data, prove of value in cation studies.

## Chemical Properties of Soils

The pH of the soils that were sampled at the three sites all contained reasonably close values with the Manhattan soil having the highest surface pH and the El Dorado soil having the lowest surface pH. At the five-inch depth however, the values were all quite close. As previously noted, the pH decreased slowly but steadily with depth in the profile (see Fig. 33).

The oxidizable material in the soils followed the same trend as the pH, being highest at the surface and decreasing with depth (see Fig. 34). The Manhattan site contained considerably more oxidizable material than the other two sites, having over 14% at the surface as compared to 7.3% at Council Grove and 6.04% at El Dorado. The reason for this wide variation is not evident at this time but probably reflects the fact that the Manhattan site was the best range site.

Cation exchange studies were performed on these soils just as they were performed on the dust samples. Results were listed in Table 8.

Table 8. Milliequivalents of Ca, Mg, and K, per 100 grams of Florence soil at the three listed sites and at the designated depths.

| | Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Manhattan | | | Council Grove | | | El Dorado | | |
| Depth | Ca | Mg | K | Ca | Mg | K | Ca | Mg | K |
| Inches | me | me | me | me | me | me | me | me | me |
| 0.0 - 0.5 | 21.0 | 6.5 | 1.7 | 10.4 | 4.3 | 0.9 | 8.1 | 2.6 | 0.9 |
| 0.5 - 1.0 | 24.0 | 6.9 | 1.7 | 10.4 | 4.7 | 0.7 | 7.8 | 2.5 | 0.7 |
| 1.0 - 1.5 | 21.9 | 6.4 | 1.6 | 10.4 | 4.5 | 0.7 | 7.1 | 2.4 | 0.5 |
| 1.5 - 2.0 | 17.7 | 5.4 | 1.1 | 10.0 | 4.3 | 0.5 | 7.3 | 2.4 | 0.5 |
| 2.0 - 3.0 | 21.2 | 6.1 | 1.1 | 10.3 | 4.4 | 0.5 | 7.4 | 2.4 | 0.5 |
| 3.0 - 4.0 | 19.2 | 5.6 | 0.7 | 9.8 | 4.4 | 0.3 | 7.4 | 2.6 | 0.5 |
| 4.0 - 5.0 | 19.3 | 5.9 | 0.7 | 10.0 | 4.5 | 0.3 | 7.5 | 2.2 | 0.5 |

## Radioactive Studies

Because Red China was supposed to have detonated a very "dirty" atomic explosion in the spring of 1966, the samples for April, May, and June were checked for radioactivity through the courtesy and cooperation of the Department of Nuclear Engineering, Kansas State University. The results indicated,[8] however, that at no time was there enough radioactive material contained in the

[8] Personal communication, Mr. Dean Eckhoff, Department of Nuclear Engg., Kansas State University, Manhattan, Kansas.

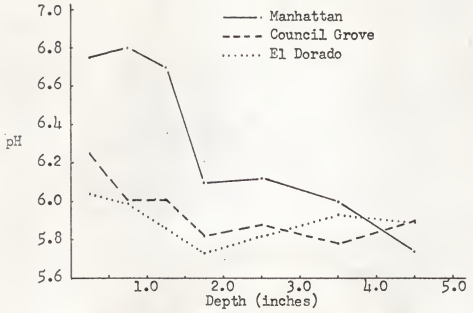



Fig. 33. The pH of the Florence soil at various depths in the soil profile at the Manhattan, Council Grove, and El Dorado sites.

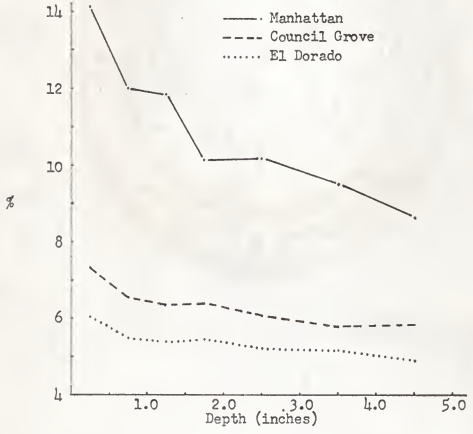



Fig. 34. Percent oxidizable material of the Florence soil at various depths in the soil profile at the Manhattan, Council Grove, and El Dorado sites.

monthly dust catch to be measurable when analyzed using the sodium iodide scintillation crystal. Thereafter, no more results were obtained.

## DISCUSSION

### Quantity of Dust

The quantity of dust that settled from the atmosphere over the Florence soil region of eastern Kansas was such that if the average of the four replicates at the Manhattan site was to be considered as representative, it would require 6,730 years for enough dust to accumulate to build an acre-furrow-slice of soil. This is based on the results of the data collected in which the average total amount of dust caught in the four replicates amounted to 322 pounds per acre for the 13 month period August 1965 through August 1966. However, the above statement must be qualified in that there could be no loss of any of the dust such as by the oxidation of the organic portion or the loss of the mineral grains through wind or water erosion. That no such loss would occur is inconceivable; oxidation most certainly will proceed, as will wind and water erosion.

In addition to the factors listed above, there are other factors which must not be overlooked as an influence on the amount and rate of atmospheric dust deposition or movement. Certainly one of the more important of these factors in the Florence soil region is the effect of the vegetation itself upon the atmospheric dust. As dust accumulates, vegetative growth occurs, and as this vegetation develops, more dust is caught and less is lost through erosion, creating an accelerated buildup of soil. However, during periods of drought, vegetation decreases and some wind erosion does occur. During extended periods of drouth a great deal of wind erosion may occur. Therefore in a grassland region like the Flint Hills region of Kansas where livestock has always been the

mainstay, drouth accompanied by over-grazing will greatly increase the amount of local atmospheric dust and soil surface loss due to near denudation of vegetation and trampling of the soil surface by livestock. Increased temperatures and increased wind velocities commonly accompany drouth conditions, which in turn further promote the loss of the soil surface.

Offsetting this loss of the Florence soils during drouth however, is the increased deposition of atmospheric dust upon these soils. This dust is picked up from cultivated or windblown areas surrounding this region by high wind currents, carried into this region and deposited upon the soil surface as the wind velocities recede.

Because of this constant interchange of the surface of the Florence soil, it would be difficult to place an absolute quantitative value on the influence that atmospheric dust has upon the surface five inches of this soil. However, from data obtained in this study, it is apparent that some dust influence is reflected in the Florence soil.

In this study, it was apparent that there was not much relationship between the quantity of dust collected, and the average monthly precipitation despite the fact that rain drops need a solid nucleus around which to form. There is a sort of opposing forces system in operation here in which the rain wets the soil surface, discouraging local soil surface loss, and yet the rain drops require this solid nucleus supplied by atmospheric dust in order to form. Undoubtedly some other factors enter in here. For the Florence soils region, it is debatable as to the amount of influence these dust nucleii would have because some runoff is certain to occur due to steepness of slope and average intensity of rainfall, thereby removing some of these particles before they even have an opportunity to be incorporated into the soil. During those periods of gentle rainfall however, when no runoff occurs, then these solid raindrop

nuclei would certainly be added to the soil surface, lending what influence they might have. As shown graphically in Fig. 6, there appears to be little or no interdependence between average monthly precipitation and dust deposition. The computed correlation coefficient substantiated this, yielding an r value of only +.148.

Slightly different from the precipitation vs. dust quantity relationship, shown both graphically and statistically, is the wind velocity vs. dust relationship. From Fig. 7 it is apparent that there may be some interdependence between the average monthly wind velocity, especially at Dodge City, Kansas, and the amount of dust falling at Manhattan. This phenomenon has been observed and recorded by other writers (6), (12), (14), etc. The statistical correlation coefficients were r = +.201 for the average monthly wind velocity at Topeka, Kansas and the Manhattan dust, and r = +.676 for the average monthly wind velocity at Dodge City, Kansas and the Manhattan dust. With the exceptions of the average wind velocity at Dodge City being considerably higher than that at Topeka, the month of June 1966 when the average wind velocity increased at Dodge City and decreased at Topeka, the two curves were somewhat similar. However, because both the wind velocity at Dodge City and the amount of dust caught at Manhattan increased in magnitude for this month, it is apparent that wind velocities on the windward side of the Flint Hills region of eastern Kansas must have an influence on the amount and kind of dust which is blown into this region.

## Soil Conditioning Effects

Following the concepts and teachings of most geomorphologists, the ultimate land forms that exist in nature over geologic time are due more to the effects of erosion, or removal, of the soil material than to the effects of deposition. This is necessary for peneplanation to occur. However, the

deposition of dust upon the soil surface during the development of this stage will certainly have some modifying influence upon the soil, not only on the morphology of the surface, but also in its textural, structural, mineralogical, and plant nutrient element content.

Referring to Table 2 it is clear that most of the dust particles from atmospheric dust fall into two catagories: either quartz or aggregates. The quartz fraction which ranged from clay size to sand size and averaged 10-30 microns is noted for its resistance to weathering and could quite conceivably modify slightly the surface horizon of an extremely fine textured soil such as would be derived from a parent material like clay shale. The aggregate fraction, on the other hand, would have just the opposite effect in that it is largely made up of clumps of smaller aggregated particles and upon being added to an already existing soil surface would probably cause a finer textured soil than that which was already present. Because the Florence soils are derived from limestones and shale residuum and because these strata contain both a fine and coarse fraction, the actual influence of atmospheric dust upon the texture of the Florence soil is debatable. However, the data listed in Table 3 indicate that there is a difference between the surface of the soil and the soil at the five inch depth in that the surface contains more aggregated particles than the soil at depth. There is no reason to believe that normal weathering under existing climatic conditions would promote this kind of change, whereas by continuously adding atmospheric dust, such a change could be accounted for. Therefore, it must be assumed that atmospheric dust does have a modifying influence, however slight it may be, upon the textural characteristics of the Florence soils of eastern Kansas.

Although not shown in Table 2, the microcline and orthoclase grains were almost always present in the sand and silt fraction of the dust but not in very large amounts. It is felt that there may be some merit in the assumption that

they could be somewhat influential in the replenishment of potassium to some soils. The quantity was small enough that no attempt was made to arrive at a percentage figure. However, if one were to consider all the potassium bearing minerals, including the illite clays, then the potassium percentage of the dust may often appear in measurable or significant amounts. Keeping this in mind, and considering spreading this amount over geologic time, it is quite possible for potassium replenishment of soils from atmospheric dust to occur. The above statements were based partly on the following observations noted in the microscopic study of the dust and of the soils. The dust fraction nearly always had a small number of readily identifiable microcline and orthoclase grains present on the mounted slide as studied under the microscope (see Fig. 35, Plate II). These grains, especially microcline, were never present in great enough amount to be considered a percentage of the total, nevertheless, they were present, and most of the time, they were fairly large--usually above 30 microns and often above 100 microns,--very angular, and quite fresh. Upon studying the sand and silt fraction of the soils, it was found that at the Manhattan site the microcline particles were present in slightly greater abundance in the top 1/2 inch of soil than at the five inch depth (see Figs. 36 and 37, Plate II). Also the greatest number of large grains occurred at the surface, as well as the most angular and least weathered. As the study progressed deeper into the soil horizon, these grains became increasingly smaller and more rounded, until at the five-inch depth, they were present in the least number, were smaller in size, and were more rounded than anywhere else in the profile. The Council Grove and El Dorado samples did not exhibit these phenomena so distinctly with the exception of the grains becoming somewhat more rounded with depth. The above grain degradation process must certainly be expected, however, due to natural weathering of the soil building minerals. As stated above, deposition

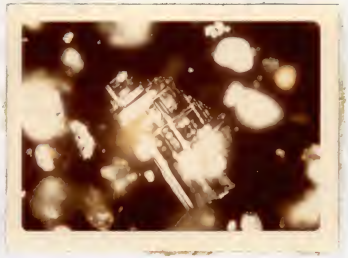
## EXPLANATION OF PLATE 2

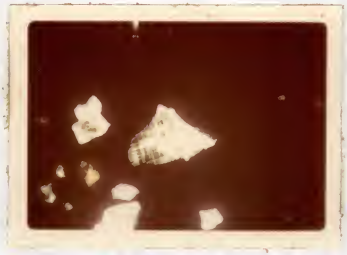
Fig. 35. Photomicrograph of a microcline grain, approximately 75 microns in length, found in a dust sample collected from the atmosphere.

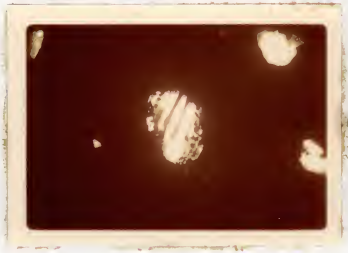
Fig. 36. Photomicrograph of a microcline grain approximately 55 microns in length, found in the surface 1/2 inch of soil at the El Dorado site.

Fig. 37. Photomicrograph of a microcline grain approximately 46 microns in length, found at the five inch depth of soil at the El Dorado site.

PLATE II







of atmospheric dust would in turn promote a natural enrichment of the soil with available potassium, especially in areas where potassium bearing minerals are in scant supply in the parent material. The presence of these minerals in atmospheric dust is explained by Black (2) when he stated that potassium-bearing minerals are nearly always present in soils, supplying these soils with from 0.3% to as much as 2.5% potassium. Therefore, any dust which is picked up by strong wind currents should contain some of these potassium bearing minerals. The greatest replenishment effect would of course occur when dust, which was picked up from a region rich in potassium-bearing minerals, was deposited in a region in which a low percentage of potassium-bearing minerals was present. A chemical analysis of the Florence soils at the various sampled depths was not made in this study, however from the preceding data, it appears that these minerals, distributed by wind currents over this region, may have a mineral-nutrient replenishment effect upon the Florence soils of the study area. More intensive and longer term studies concerning this relationship are needed.

## Clay Minerals

As previously stated, when enough dust was caught, it was fractionated between clay-sized and sand-and silt-sized minerals. The clays then were identified as to the kinds and relative amounts present, using the X-ray diffractometer.

The results shown by these diffractograms of the dust clays indicated that illite clays were present at all the sites over the term of the study for all the months except August, 1965 when only one site gave evidence of this clay. April, 1966 results also indicated a very low amount of illite, the only clay present. The illite clays were also usually present in greatest amounts;

kaolinite clay followed illite closely in monthly occurrence and total amount; montmorillinite was frequently present but only in small amounts while quartz and feldspar minerals were commonly present although also in small amounts. In a few samples, very small amounts of unidentifiable minerals were occasionally present.

Like the sand and silt fraction, the clay fraction of the dust that was collected at these three sites was thought to be present, both in great enough quantity, and frequently enough, to be of value in soil formation. Also, the kinds of clays present as well as their relative concentration would have an influence, not only on the structural and textural characteristics of the soil but also on the fertility level of the soil and the kind and amount of vegetation it would support. As seen from Figure 8, the percentage of the clay-sized material present in the dust for the period August, 1965 through August, 1966 ranged from a low of about 20% to a high of just over 70% with a mean of around 42% per month. This is only nine percent more than the average of the soils (approximately 33%) but because of its persistence, over a geologic time span, this additional amount would almost certainly have its influence.

The data collected from the clays of the soil reflect more the modifying influence of the clays of the dust than is reflected by the data collected from the dust clays themselves. Referring to Table 4, it is seen that the Manhattan soils yielded the greatest percentage of clay-sized material with around 50%, Council Grove was second with around 30% while El Dorado yielded the least amount with about 20%. There is no clear-cut explanation for this difference but probably is the result of several factors. It is felt that one of these factors is the quality and quantity of the vegetation at these sites which is, among other things, directly the result of grazing practices, as well as the location in the landscape. Although no range classification

determinations were made, the author feels qualified to state that the best rangeland site existed at the Manhattan site, with the Council Grove and El Dorado sites more nearly equal but poorer in range quality. Because of the better quality vegetation at the Manhattan site, possibly more of the dust which settled there was incorporated into the soil than at the other two sites where more of the dust, especially the clay fraction, might have been lost through erosion. Tables 4 and 5 also clearly indicate that the smallest percentage of total clay material exists in the top 1/2 inch of soil and the most at the 4 to 5 inch depth, but that the greatest percentage of the coarse clays are present in the top 1/2 inch of soil and the least percentage at the 4 to 5 inch depth. Just the reverse existed in the case of the fine clay material with the least percentage in the top 1/2 inch of soil and the greatest at the 4-5 inch depth. Therefore, because the coarse clays, specifically illite and kaolinite, were more abundant at the soil surface, and because the X-ray diffractograms of the clays of the dust indicated a greater predominance of the coarse clays (illite and kaolinite in that order), then there is every reason to believe that there is a relationship between the two. That is, the clay fraction of atmospheric dust may exhibit a modifying influence upon the clay characteristics of the surface of the Florence soil.

## Exchangeable Cations

In addition to having a potential for physical modification of the surface of the Florence soil, atmospheric dust also exhibits an exchangeable cation influence, at least for calcium, magnesium, and potassium, upon the Florence soil. Some of this influence can probably be traced directly back to the higher percentage of clays in the dust, recognizing the fact that the clays, especially montmorillonite, are the major sites for the exchange capacity of

the soil itself. As seen from Tables 6 and 8, the milliequivalents of these three cations were much greater in the August sample of dust than at any level in the top five inches of soil. This was further documented in that the greatest amount of these cations existed in the top 1 inch of soil, and the least at the five-inch depth for all three soils and for all three cations. The January sample, on the other hand, did not exhibit this clear-cut distinction, however, this month's sample had been diluted in the container with ethylene glycol to resist freezing and it is thought that this treatment may have influenced the sample in some manner to produce inaccurate results. Prompting this statement is the fact that the quantity of the calcium ion in the dust was only reduced moderately, still being in greater concentration than in the soil, while Mg was reduced drastically and K suffered near total annihilation. True, the amount of these cations will vary from month to month in the dust, but it is not believed that a variation of this magnitude is normal. Of course, it has been recognized that a certain amount of translocation of these cations from the root zone to the soil surface by plant growth will occur.

The amounts of the macro--nutrients supplied by the dust to the soil would probably not be of as much influence on plant growth, however, as the amounts of the micro--nutrients, assuming that micro--nutrient elements are present in the dust. Therefore, on the basis of these data, it is felt that atmospheric dust does have a modifying influence upon the exchange capacity as well as upon the physical characteristics of the surface of the Florence soil of eastern Kansas. Certainly, more work needs to be directed towards studying these phenomena.

## Origin of Dust

The data resulting from this study indicate that there is little reliability in the use of atmospheric dust as an indicator of its exact place of origin. Most of the results indicated a general area, or region, of origin but nothing specific could be determined. For example, the average pH of the dust was higher during the year of collection than the pH of the soil, thus suggesting a dust origin from soils with higher pH's, namely those west of this area (See Figs. 29 and 33) but it does not identify the specific area of pickup. The organic matter fraction was likewise higher in the dust than in the Florence soil (see Figs. 30 and 34), suggesting an area of dust origin with high surface organic-matter content. But no specific location or area can be pinpointed. Possibly increased study of plant phytoliths will have some bearing on this problem. The high correlation coefficient existing between the amount of dust caught at Manhattan and the average monthly wind velocity at Dodge City also suggests a general region of dust origin, however, this too, is somewhat more regional than specific. Therefore, it is felt that it is quite possible to use the dust as a regional indicator of its place of origin but as yet it cannot be used as a specific place of origin determiner. The mineralogy of the sand and silt fraction of the dust did not yield any data of value in this respect except the presence of the relatively large angular feldspar crystals. This again, is indicative of a region of less active chemical weathering.

The initial design of this study included the spacing of the three sites a certain distance apart, in this case about 35 miles, to check the possibility of a climatic or other difference existing between them, even though the Florence soil and its parent material is easily identified well beyond these limits. The resulting data indicate that the average amount of dust caught

at the south site (El Dorado) for the period of study was somewhat higher than at the other two sites, but not unanimously so. The term "unanimously" was used here because the El Dorado site was significantly higher than the two lowest producing replicates at the north (Manhattan) site, but was not significantly higher than the other two replicates. The data resulting from the clay studies as well as from the microscopic studies did not yield any particularly obvious characteristic or trend which would be indicative of a climatic difference between the two most distant sites. Therefore, apparently no modifying characteristic exists due to climatic conditioning factors over a 100 mile distance, in a north-south direction, through the Florence soils region of eastern Kansas.

Similarly, the design of the experiment included one container which was elevated to a height of 16 feet to check and measure any difference in dust quantity or quality between it and the surface containers at the Manhattan site. The results indicate that there was not much difference in the amounts or kinds of clays present in the dust between these two sites, with the exception of March, when montmorillonite appeared strongly in all the surface replicates but was nearly absent in the elevated container, and July (elevated sample was contaminated), when the elevated sample yielded high amounts of amorphous material while the surface containers yielded high amounts of illite.

Contrary to the similarity exhibited by the clays, the microscopic study of the sand and silt fractions between these two sites yielded results which were somewhat different. These differences are not yet fully explainable or understood. The surface containers consistently yielded higher percentages of quartz than any other mineral although there were three months with high percentages of phytoliths and one month with a high percentage of aggregated material (see Table 2). The elevated container, on the other hand, yielded

consistently high percentages of aggregated material and somewhat lower percentages of quartz. This difference persisted despite the fact that both samples were collected the same time, in the same manner, and were processed and analyzed identically. Also, as noted above, the percentage of clays of the elevated sample corresponded quite closely with the percentage of clays of the surface sample, forcing close correspondence between the percentage of sand and silt fractions. One explanation for this difference lies in the possibility that the quartz grains of the sand and silt fraction of the elevated samples may have contained partial or thin coatings of cemented colloidal material either organic or inorganic, and although resembling aggregated particles, were in actuality true sand or silt particles as in the surface container. The fractionation procedure might possibly have been too gentle to break down the cementation. Certainly more work needs to be performed on this phase of the study in which an increased amount of the sample needs to be obtained, possibly through consolidation, different or more violent methods of fractionation need to be tried, and more intense methods of study need to be sought, such as electron microscopy, D.T.A. etc.

Regardless of the possible differences exhibited by the sand and silt fractions between the two sites, there was apparently no difference in the kind or quality of dust which settled at the two sites. This statement is based upon the fact that there was no significant difference inquantities of dust between the two sites, there were no obvious differences between the clay kinds of percentages, and there were no large differences between quantities of exchangeable cations between the two sites (see Table 6).

## Organic Matter

That portion of the dust settling from the atmosphere which was destroyed by repeated applications of 30% hydrogen peroxide was considered organic matter

and is shown graphically in Figures 30 and 32. It is apparent that all the sites maintained a reasonably uniform monthly percentage except the month of April, in which a fairly wide difference in percentage existed between the Council Grove and the El Dorado sites, and also the month of June, in which a wide difference developed between the elevated site and the surface sites. From these data, it is obvious that a seasonal trend occurred in which the greatest amount of organic matter was present in the dust during the fall months with a maximum of 36% while the rest of the year maintained a fairly uniform range of from 10 to 16%.

The organic matter content of the soils is shown graphically in Figure 34 and indicates a high at the surface, decreasing with depth. The samples at the Manhattan site contained the greatest amount, 14% at the surface decreasing to 9% at the five inch depth, while the samples at the Council Grove and El Dorado sites contained only 7.4% and 6% decreasing to 6% and 5% respectively. This is confirming evidence as to the Manhattan site being the best range site.

Because organic matter is continuously being added to the surface of the Florence soil by plant growth, it would be difficult to place an absolute quantitative value on the benefits that this soil receives through the accumulation of the organic material of the dust. However, because the organic content of the dust is higher than the organic content of the soil surface, then some benefit is certain, not only through the modification of the physical characteristics of the soil, but also through the modification of its chemical characteristics.

pH

Graphical representation of the pH of the atmospheric dust that was collected at each of the sites is shown in Figure 29. This characteristic of the dust was quite variable over the period of study but it did appear that there might be a seasonal trend with the higher average monthly pH during the winter and spring months. The range of pH was from about 6 to 8 and averaging 6.7.

The pH of the soils at all three sites was also taken and is also graphically represented in Figure 33. Again, as with the organic matter, the Manhattan site exhibited the highest pH followed by the other two at a somewhat lower pH. The pH at the two north sites follow a trend, being highest at the surface and decreasing with depth while at the El Dorado site, the trend is not so obvious. Nevertheless, the highest pH always occurred in the top one inch of soil with highs of 6.8 at Manhattan to 6.0 at El Dorado.

Because the highest pH occurs at the surface of the soil and because the pH of the dust is consistently above that of the soils, it would appear that the dust has some modifying influence upon the surface of the Florence soils, especially when carried on over a period of geologic time with its many fluctuations in climate.

## Solution Analysis Results

An aliquot of the liquid which was maintained in the containers at each of the sites was collected for the month of August, 1966, and sent to the previously mentioned laboratory for solution analysis of the cations which might go into solution. Analysis results were obtained for five elements, including Ca, Mg, K, P, and Na (see Table 7). The resulting data indicated that for

this one month, the quantities of each of the different elements at each site was fairly uniform in pounds per acre except sodium, which exhibited a relatively wide range between sites. These elements are all available from most soils for dust transport to this area except sodium. This cation was present in greatest amount, but is generally not considered to be present in the soils west of this region in great enough quantity to be a major problem. Possibly this is the result of what Sears identified as "tiny salt crystals". Small areas of intrazonal soils containing this cation exist as is recognized, but it is questionable whether these soils furnished as much soluble sodium as was present in the liquid trapping solution of the dust sample. More and longer term, studies, need to be carried out examining this phase of the study.

## Dust Radioactivity

Following the Red Chinese detonation of one of their atomic devices in the spring of 1966, some dust samples were analyzed for the presence of radioactive particles supposedly contained in the cloud of atomic debris which passed over the United States a few days later. The dust for the month prior to the detonation, and the three months following, were studied for the presence of this radioactive material. The preceding month's data were to serve as a check for the following months of data. These data indicated that there was not a measurable amount of radioactive material being retrieved in these containers for these four months when analyzed using the sodium iodide scintillation crystal. The use of other more precise methods of analytical procedures might possibly have produced slightly different results, however, for the purpose of this study, it was not considered important. Therefore, it is apparent that the addition of radioactive material, originating on the other side of the world, is of no immediate importance to the productive ability or physical characteristics of the Florence soil.

## Statistical Results

As previously stated in the results section, the statistical analyses of this study consisted of three analysis-of-variance studies, one Duncan's NMRT test, and three correlation studies. However, because all the data were not usable (missing or biased) it is felt that the data which were used, and the methods or formulas which were used, should be listed.

The data used to determine the analysis-of-variance testing the quantity of dust settling from the atmosphere between the different sites and between the different months are listed in Table 9.

Table 9. The data used in determining the analysis-of-variance for the quantity of dust between sites and between months.

| Location | site | Monthly amounts (Pounds per acre). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Apr. | May | Jul. | Aug. |
| (Manhattan surface replicates) | 1 | 46 | 29 | 14 | 14 | 8 | 8 | 6 | 28 | 32 | 31 | 25 |
| | 2 | 46 | 26 | 13 | 12 | 7 | 7 | 6 | 30 | 36 | 28 | 24 |
| | 3 | 47 | 28 | 13 | 11 | 7 | 8 | 5 | 38 | 35 | 29 | 25 |
| | 4 | 65 | 27 | 16 | 13 | 7 | 8 | 6 | [47] | 45 | 31 | 23 |
| Manhattan (elevated) | 5 | 56 | 34 | 15 | 14 | 12 | 11 | 10 | 24 | 59 | 103 | 38 |
| Council Grove | 6 | 61 | 29 | 16 | 11 | 10 | 6 | 12 | 107 | 57 | 28 | 31 |
| El Dorado | 7 | [65] | 27 | 14 | 12 | 8 | 6 | 5 | 68 | 47 | 95 | 73 |

It will be noted that the March and June 1966 data were discarded.

The boxed figures were figures which were computed by the missing data formula which is as follows:

Estimate Xij by $x.. + (Xi. - x..) + (X.j - x..) = Y_o$

Then $X_{kl} = \frac{tT_k + rB_l - G}{(t-1)(r-1)} = X_1$, $G = G_o + Y_o$

$Y_1 = \frac{tT_i + rB_j - G}{(t-1)(r-1)}$, $G = G_o + X_1$

Continue the two steps above until no change occurs in $X_1$ or $Y_1$.

$T_i$ = sum of ith treatment,
$B_j$ = sum of jth block,
$G$ = grand total of (t r - 1 ) elements.

The degrees of freedom were also reduced by two.

These data produced F values listed below. The rejection F values are also listed.

| | Computed F | Rejection F 5% | Rejection F 1% |
|---|---|---|---|
| Between sites (quantity of dust) | 2.56 | 2.28 | 3.17 |
| Between months (quantity of dust) | 12.247 | 2.02 | --- |

Because there was a significant difference between sites but no highly significant difference, the Duncan's NMRT test was employed to determine which means were significantly different, as follows:

| Site numbers | 7 | 5 | 6 | 4 | 3 | 1 | 2 |
|---|---|---|---|---|---|---|---|
| Ordered array of means | 38.18 | 34.18 | 33.45 | 26.18 | 22.36 | 21.91 | 21.36 |

The calculated values used in this determination were:

$S_{\bar{x}} = 5.4129$.

| | P = 2 | P = 3 | P = 4 | P = 5 | P = 6 | P = 7 |
|---|---|---|---|---|---|---|
| $100_{\alpha}$ %q.05 | 2.83 | 2.98 | 3.07 | 3.14 | 3.20 | 3.24 |
| $R_p^{\alpha}$ | 15.31 | 16.12 | 16.61 | 16.99 | 17.31 | 17.53 |

These computations illustrated that the difference existed between the El Dorado site (site 7) and two of the Manhattan surface replicates (sites 1 and 2).

The analysis-of-variance of the percent organic matter content of the dust between months and between the sites used the data as listed in Table 10.

Table 10. The percentage of organic matter of the dust for the period August, 1965 through July, 1966 as was used in computing the analysis-of-variance.

| Site | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Jul. |
| | % | % | % | % | % | % | % | % | % | % | % | % |
| 1 | 10 | 21 | 13 | 20 | 37 | 28 | 21 | 0 | 17 | 5 | 6 | 8 |
| 2 | 5 | 10 | 6 | 17 | 22 | 17 | 15 | 5 | 11 | 5 | 4 | 4 |
| 3 | 7 | 18 | 5 | 19 | 22 | 20 | 13 | 6 | 29 | 13 | 9 | 15 |
| 4 | 7 | 16 | 8 | 14 | 15 | 16 | 12 | 5 | [20] | 30 | 3 | 10 |
| 5 | 1 | 13 | 15 | 13 | 10 | 18 | 9 | 12 | 21 | 19 | 30 | 23 |
| 6 | 1 | 16 | 11 | 23 | 23 | 30 | 0 | 10 | 11 | 9 | 10 | 12 |
| 7 | [3] | 16 | 16 | 28 | 23 | 23 | 0 | 10 | 36 | 10 | 13 | 10 |

Boxed values are missing data which were computed using the missing data formula previously described.

The computed F values and the rejection values for these data were:

| | Computed F | Rejection F 5% | Rejection F 1% |
|---|---|---|---|
| Between sites (% organic matter) | 1.16 | 2.27 | 3.13 |
| Between months (% organic matter) | 5.10 | 1.98 | ---- |

No Duncan's NMRT was performed on these results as no significance existed between sites. Highly significant differences, however, did exist between months. Although the data, as listed in Table 10, appear to be quite wide in variation for some months, over the year as a whole this variation is cancelled, resulting in no significant difference between sites.

Finally, the analysis-of-variance of the pH of the dust between the sites and between the months in which the data were collected was determined using the data shown in Table 11.

Table 11. The pH of the dust for the months September 1, 1965 through July, 1966 as was used in computing the analysis-of-variance.

| Site | Month | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July |
| | pH | pH | pH | pH | pH | pH | pH | pH | pH | pH | pH |
| 1 | 7.0 | 6.8 | 6.2 | 6.3 | 7.5 | 6.7 | 6.3 | 8.0 | 6.2 | 6.4 | 6.4 |
| 2 | 7.0 | 6.5 | 6.7 | 6.5 | 6.9 | 7.0 | 7.5 | 7.5 | 6.5 | 6.5 | 6.1 |
| 3 | 7.0 | 6.4 | 6.3 | 6.3 | 7.0 | 6.0 | 7.5 | 7.3 | 6.0 | 6.0 | 6.2 |
| 4 | 7.5 | 6.3 | 6.5 | 6.7 | 6.7 | 7.5 | 7.8 | [7.8] | 6.0 | 6.2 | 6.1 |
| 5 | 7.0 | 6.4 | 6.0 | 6.5 | 7.1 | 6.3 | 7.5 | 7.0 | 6.1 | [6.0] | 6.2 |
| 6 | 7.5 | 6.4 | 6.0 | 6.5 | 7.1 | 6.9 | 7.0 | 7.5 | 6.4 | 5.8 | 6.3 |
| 7 | 6.8 | 6.2 | 6.0 | 6.8 | 7.0 | 6.8 | 7.3 | 6.8 | 5.4 | 6.0 | 6.1 |

Boxed values were missing data which were computed using the missing data formula previously described.

The computed F values and the rejection values included:

| | Computed F | Rejection F | |
|---|---|---|---|
| | | 5% | 1% |
| Between sites (ph level) | 2.00 | 2.28 | 3.17 |
| Between months (pH level) | 19.44 | 2.02 | ---- |

Again, highly significant differences did occur between months while significance did not occur between sites, therefore, no NMRT test was performed.

The correlation values which were computed used only the pounds per acre of dust which was retrieved in the four surface replicates at the Manhattan site, the average monthly precipitation values at Manhattan, the average monthly wind velocity at Topeka, Kansas, and the average monthly wind velocity at Dodge City, Kansas. The pounds per acre values used in computing these results are listed in Table 12.

Table 12. Pounds per acre of dust which were caught in the four Manhattan surface replicates and which were used in computing correlation values.

| Replicate | Pounds per acre per month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. |
| 1 | 46 | 29 | 14 | 14 | 8 | 8 | 6 | 25 | 28 | 32 | 51 | 31 |
| 2 | 46 | 26 | 13 | 12 | 7 | 7 | 6 | 40 | 30 | 36 | 50 | 28 |

Table 12. (cont.) Pounds per acre of dust which were caught in the four Manhattan replicates and which were used in computing correlation values.

| Replicate | Pounds per acre per month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. |
| 3 | 47 | 28 | 13 | 11 | 7 | 8 | 5 | 47 | 38 | 35 | 49 | 29 |
| 4 | 65 | 27 | 16 | 13 | 7 | 8 | 6 | 79 | 39 | 45 | 50 | 31 |

The boxed value was computed using the missing data formula as previously described.

The average monthly values used in computing the correlation coefficients were:

| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manhattan precipitation | 3.1 | 8.5 | 1.3 | 0.35 | 2.2 | 0.4 | 0.7 | 0.0 | 1.8 | 1.7 | 16.0 | 2.3 |
| Topeka wind velocity | 7.4 | 9.1 | 8.1 | 7.6 | 10.1 | 10.2 | 8.7 | 13.1 | 11.2 | 9.8 | 9.1 | 8.0 |
| Dodge City wind velocity | 11.5 | 13.2 | 11.6 | 11.6 | 12.8 | 11.8 | 11.4 | 16.1 | 14.3 | 14.0 | 16.2 | 13.4 |

The computed correlation values were:

Quantity of dust vs. average Manhattan precipitation $r = +.148$

Quantity of dust vs. average Topaka wind velocity $r = +.201$

Quantity of dust vs. average Dodge City wind velocity $r = +.676$

The formula used in computing these values was:

$$r = \frac{\Sigma(xy)}{\sqrt{\Sigma(x^2)\ \Sigma(y^2)}}$$

where $x = (X_{ij} - \overline{X})$ and $y = (Y_{ij} - \overline{Y})$

The regression equation used to determine the regression line was:

$$E = \overline{Y} + \frac{\Sigma xy}{\Sigma x^2} \quad (X - \overline{X})$$

The linear regressions determined were as follows.

Regression equation for Manhattan dust vs. Manhattan precipitation:

$$Y = 1.13X + 24.7$$

Regression equation for Manhattan dust vs. Topeka average monthly wind velocity:

$$Y = 2.1X + 7.32$$

Regression equation for Manhattan dust vs. Dodge City wind velocity:

$$Y = 6.78 X - 62.22$$

## SUMMARY

This study of the quantitative and qualitative aspects of atmospheric wind borne dust was initiated in August 1965, in which seven identical screened containers, two feet high and eight inches in diameter (standard rain gauge containers), were set up on soil identified by qualified soil scientists as the Florence soil. These seven containers were set up at three different sites, five containers including one elevated to 16 feet, north of Manhattan, one container south of Council Grove, and one container northeast of El Dorado, Kansas. The outermost sites were separated by a distance of approximately 100 miles in a north-south direction to check the possibility of climatic or other differences over this distance. Statistical analyses-of-variance results indicated that at the 5% level, there was a significant difference in the quantity of dust caught between two of the Manhattan surface replicates and the El Dorado site for the period August 1965 through August 1966. There was no significance at the 1% level. Differences between months were highly significant (1% level). The lowest deposition rates occurred during January and February, 1966 and the highest deposition rates occurred during March and June, 1966. Further analyses-of-variances indicated that there was no significant difference

between sites for either the organic matter content or pH of the dust during the term of this study, while a highly significant difference (1% level) existed between months for these two variables.

There did appear to be a difference (not tested statistically) in the soil pH and the percent oxidizable material of the soil between the three sites with the south site (El Dorado) indicating the lowest pH and the lowest percent organic matter, while the north site (Manhattan) indicated the highest. Although climatic differences may be a factor here, a comparison of the range sites in which the sites are located exhibited more of a management influence than a climatic influence.

The rate of dust deposition appeared to follow a seasonal trend, being lowest during the winter months of December, January, and February, and highest during March through June.

The standard deviation for the four replicates at the Manhattan site ranged from 0.50 to 20.29 pounds per acre, and averaged 3.65 pounds per acre. Only occasionally did one of the replicates exhibit a quantity very different from the other three. The variation between sites was also quite small until feeding and grazing operations in the spring of 1966 influenced the quantity of dust collected at Council Grove, and bird droppings influenced the quantity of dust collected in the elevated container at the Manhattan site.

Although past literature has indicated that there is some interdependence between rainfall and the amount of dust carried to the earth's surface, data in this study showed little correlation between these two variables. A higher correlation existed between the average monthly wind velocities, especially at Dodge City, and the amount of dust collected at Manhattan than was evident with the precipitation variable.

From these relationships, it would appear that the wind velocities to the windward side of this region are more influential on the amount of dust carried into this region than are either, the wind velocities to the leeward side or the precipitation.

Assuming that the amount of dust collected during the term of this study was a representative sample of annual dust deposition, a depth equivalent to an acre-furrow-slice of soil (one acre, 6" deep), would be deposited in about 60 centuries discounting any loss.

It was determined that atmospheric dust, which settled in the Flint Hills region of Eastern Kansas, could, over geologic time, have a modifying influence on the textural, structural, and fertility level of the surface of the Florence soil. The percent of the organic matter of the dust was, on the average, as high or higher than the percent organic matter of the soil. The pH of the dust was also higher than that of the soils, leaving its influence by at least assisting vegetation in increasing the pH of the surface of the soil above that of the soil at the five-inch depth. It was further found that certain potassium-bearing minerals were commonly present in the atmospheric dust, and could quite possibly have an influence upon the total amount of this cation present in the Florence soils. This was illustrated in that microcline and orthoclase, to name only two potassium bearing minerals were commonly present in the dust where they existed in relatively large, fresh and angular grains. The soils contained these grains also, but they were most angular in the upper 1/2 inch of soil, becoming more rounded and slightly smaller at the five inch depth.

X-ray diffractograms indicated that the two major clays, illite and kaolinite, were commonly present in the dust while montmorillonite was present less often and then only in small amounts. Clay-sized quartz and feldspar minerals were also commonly present. These clays were also always present in

the clay fraction of the soils with illite, kaolinite and quartz dominating the coarse and medium clays and montmorillonite dominating the fine clays.

Results which are indicative of the origin of the dust which settled over the Flint Hills region of eastern Kansas included the high correlation between the amount of dust collected at Manhattan and the Dodge City wind velocity as well as the results which indicate that dust, reported to have originated in New Mexico, nearly doubled the total amount of dust retrieved at Manhattan for March 1966. These data also showed that the dust from New Mexico contained only small amounts of montmorillonite clays whereas the dust from the remainder of the month's collections contained the greatest amount of montmorillonite clays encompassed by any month during this study.

Solution analysis of the suspending media of the dust indicated that soluble cations were always present, with calcium being present at a concentration of less than two pounds per acre, magnesium and potassium less than one pound per acre, phosphorus less than 1/10 pound per acre, and sodium being most abundant with over nine pounds per acre in one container. The quantities of sodium between sites were quite variable. These results were for only the month of August 1966.

Also, the dust from the Manhattan site for September 1966 and January 1967 was analyzed for exchangeable Ca, Mg, and K. The results for September indicated that the milliequivalents of these cations were in much greater abundance in the dust than in the soil while the results of January indicated that only Ca was present in greater amount in the dust than in the soil. Mg was present in much lesser amounts and K was almost non-existent in the January test. Possibly ethylene glycol, which was present in the water, may have had some influence on these latter results. Furthermore, the soils contained greater amounts of these cations on the surface than at the five-inch depth. Possibly

reflecting the influence of these cations in the dust.

Tests for radioactive material using the sodium iodide scintillation crystal, indicated that for all practical purposes, no measurable amounts of radioactive material were present in atmospheric dust during the spring months of 1966.

Statistical computations included three analyses-of-variance, one Duncan's NMRT test, and three correlation coefficient determinations complete with regression line computations. Results from the analyses-of-variance indicated that highly significant differences existed between months for all three analyses of the study, while differences between sites were not significant for either organic matter content or pH of the dust but were significant between sites for quantity of dust. Duncan's NMRT test indicated that this difference existed between the El Dorado site and two of the Manhattan replicates. Correlation coefficient determinations proved to be very low and not significant for precipitation vs. dust quantity ($r = +.148$), and for Topeka wind velocity vs. dust quantity ($r = +.201$), but considerably higher and significant for the Dodge City wind velocity vs. dust quantity ($r = +.676$).

In conclusion, the data obtained in this study for this period of time indicated that atmospheric dust, which settled upon the Florence soils of eastern Kansas, does have a modifying influence upon these soils. Precise determinations of this influence however, would require much more intense investigations carried on over a greater length of time.

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# THE INFLUENCE OF ATMOSPHERIC DUST UPON THE FLORENCE SOILS OF EASTERN KANSAS

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This study consisted of installing seven dust-catching containers at three different sites, the two outermost sites approximately one-hundred miles apart, and catching atmospheric dust for quantitative, chemical and mineralogical studies to determine the rate of deposition as well as the influence this dust might have upon the Florence soil. Five containers were situated at the Manhattan site for replication studies--one elevated to 16 feet and the other four resting on the soil surface. All three sites were situated upon and completely surrounded by native grassland.

The data obtained for the period August, 1965 through August, 1966 indicated a seasonal influx of dust, with the lowest monthly rate, about 6 pounds per acre, falling in midwinter and the highest rate, about 50 to 60 pounds per acre, falling during spring and summer. The average amount caught in the Manhattan replicates was 26.75 pounds per acre per month.

Dust reported to have originated in New Mexico and transported over this region on atmospheric winds nearly doubled the total amount of dust for the month of March 1966. It had slightly less montmorillonitic clays than the dust for the remainder of the month, but no other differences could be detected either in the clay or the sand and silt fraction.

The mineralogical studies of the dust using the petrographic microscope were highly variable and yielded information most valuable to the extent of the dust furnishing the soil with worthwhile (not measurable) amounts of potassium-bearing minerals. Quartz was the dominant mineral present followed by lesser amounts of opal phytoliths and aggregated material, and minor amounts of calcite, hematite and hornblende.

X-ray diffraction data indicated that with the exception of one month, clay minerals were always present with illite being most abundant, kaolinite nearly as abundant, and montmorillonite usually present but in small amounts.

Total amounts ranged from 15% to 69% clay minerals and averaged 42.2% per month for the year.

Radioactive studies of the dust following a Chinese atmospheric nuclear detonation failed to confirm any measurable amount of radioactive material settling from the atmosphere on a monthly measurement basis when analyzed using a sodium iodide scintillation crystal.

When testing for exchangeable cations, it was found that the dust for August, 1966 contained Ca, Mg, and K concentrations far in excess of the milliequivalent concentrations of these cations in the soil, but for January 1967, only Ca was in excess. The only difference in procedure was the presence of ethylene glycol in the suspending water of the January sample.

Statistical results of the analysis-of-variance for the dust quantity indicate a 5% significance between two Manhattan replicates and the El Dorado site only, when comparing sites and using Duncan's NMRT testing procedure. Differences between months were highly significant beyond the 1% level. No significant differences existed between sites for organic matter content or pH of the dust, whereas highly significant difference existed between months. Correlation coefficients indicate significant relations ($R = +0.67$) between Dodge City wind velocities and Manhattan dust quantity, a non-significant tendency($R = +0.20$) between Topeka wind velocities and Manhattan dust quantity, and an even weaker tendency ($R = +0.15$) between Manhattan precipitation and Manhattan dust quantity.